ILLUSTRATED PRACTICAL GEOMETRY.

THE ILLUSTRATED

LONDON

PRACTICAL GEOMETRY,

AND ITS APPLICATION TO

ARCHITECTURAL DRAWING.

FOR THE USE OF SCHOOLS AND STUDENTS.

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THE ILLUSTRATED LONDON PRACTICAL GEOMETRY.

INTRODUCTION.

The term Geometry, according to its strict derivation, means the "art of measuring the earth." The science is supposed to have originated with the Egyptians. The annual overflowings of the Nile caused frequent destruction to the marks and boundaries of the fields on its banks, hence the first impulse to the discovery of means whereby a knowledge of their extent and boundaries could be ascertained and recorded. Whether this be the true history of the origin of the art or not, it is not within our province to determine; like many other theories it may be more fanciful than correct. We are rather inclined to think that the science has been a strictly progressive one, a slight knowledge of its use and elements being possessed by man even in the early stages of the world's history. In daily contact with material things, the eye becomes accustomed to measure distances and scan altitudes, the river's breadth, and mountain's height,—the hand, in grasping objects, to ascertain their figure and estimate their bulk. The science of Geometry is now, however, that which investigates the properties of magnitude generally, and its relation to number,—its objects are, extension and figure.

Geometry is divided into two parts or branches—Theoretical and Practical, or Demonstrative and Constructive; in the former the principles of the science are treated abstractly,—the latter shows their application to the useful purposes of every-day life. In the varied branches of the arts and sciences, numerous are the operations performed by its aid. In the warlike operations of the "tented field," the soldier is indebted to it for assistance, in razing the fortress and cannonading the "leagured town," —the sailor, ploughing the pathless deep, owes his safe arrival in his

destined port to its unerring guidance,—the architect, in designing his specimens of the beautiful,—the engineer, in carrying out his gigantic operations,—the mechanic, in planning an automaton machine, a steam-engine, or a powerloom; all are indebted to a knowledge of its properties, and a facility in performing its constructions. And not less observable is this in the humbler walks of trade and commerce, for, in almost all of them, may its influence be traced, and its importance exemplified.

Practical Geometry is the basis of all drawing. As the combination of lines and curves of the various letters form the foundation of written language, so the like combinations in geometrical construction form, we conceive, the foundation of the art of general drawing in all its branches. We do not insist so much on the fact, that the lines and figures known as geometrical, are to be found more or less strongly indicated in all the varied and graceful forms scattered before us—floating in the air—waving in the trees—adding beauty to the rich landscape, or mirrored in our glassy ponds; but we would rather impress upon the mind of the reader the importance of the truth, that a knowledge of Geometry is essentially requisite before an acquaintance with accurate drawing is attainable. That a freedom of handling, a finish of touch, or an exquisite grace in pencilling, is attainable by desultory and long-continued practice, we do not deny, and that such attempts will often pass for correct drawing, but let them be carefully examined, and the truth will become evident; that their beauty has been merely in the execution, and their accuracy only apparent. Even in artists of acknowledged celebrity, whose works have been scarcely less admired for their originality of conception than for their exquisite colouring, defects are observable by a cultivated eye, which owe their existence to a want of geometrical knowledge. And this fault may be more frequently found than is generally acknowledged. But, a short time ago, the Master of a School of Design regretted that he could not impart a correct knowledge of the higher branches of the art of delineation, to pupils whose delicacy of finish, or other qualities, justified the attempt; because the principles and practice of perspective had to be mastered, and this was not available, from their ignorance of the MERELY RUDIMENTARY principles of practical Geometry. To us the remedy seems amazingly simple. Such a work as we now present to the Reader may be useful in similar cases, in providing means by which the requisite knowledge so desiderated may be easily imparted. We feel confident that

greater progress, even in artistic drawing—a branch generally considered as having but a slight connection with Geometry—would be made, if the pupils were, as a matter of every-day education, rendered familiarly acquainted with geometrical forms and their applications—their construction and proportions—their combination and transposition—the power of estimating distances, and the direction of lines. Drawing, in its widest acceptation, may be defined as "the art of delineating and representing forms and objects;" and as these are susceptible of the greatest diversity of change, dependent upon the position in which they are viewed, it is clearly requisite that the pupil must be able to estimate precisely the amount of such change, before the objects themselves can be delineated with accuracy. This facility of estimation is solely to be acquired by a knowledge of the constituent parts of the forms themselves, assisted by a practical adaptation of the mathematical principles which govern the laws of vision. Hence may be deduced the reason why so many fail to delineate objects accurately; having no fixed principles to which to recur, they draw them as they see them, or fancy they see them, not as they really exist or are presented to them. Nor is it till they are acquainted with the structure and combinations of the lines which form all objects, however complicated, and the laws which govern their transmission to the visual organs, that they can see the violent errors of delineation they have committed. And this essential knowledge can only be obtained by the aid of Practical Geometry. We are aware that a considerable prejudice exists in the minds of many, as to the utility to be derived from a thorough knowledge of geometrical drawing; it has been generally looked upon as only useful to the architect, the engineer and mathematician or to the operative in his workshop. Being thus looked upon as an exclusive branch of education, it has been treated as if exceedingly limited in its application. That it is not so, we trust we have already shown; and further comment as to its universal usefulness, in this the time of practical science, we deem, here at least, to be altogether unnecessary.

The following treatise has been designed to present a series of useful geometrical problems, the whole of which may be made available in the various departments of practical science; we have given none which require for their construction expensive or complicated instruments—the drawing board, square, ruler, compasses, pen, and pencil, comprising all that are requisite. We have refrained from giving those problems con-

nected with the Mensuration of Surfaces, or Heights and Distances, which require the aid of more expensive instruments, and a knowledge of principles and rules, chiefly as we conceive them to belong to the branches which should be treated of under the distinction of Theoretical and Practical Mathematics. We do not consider it necessary to take up space by describing the instruments essentially requisite; all that is required is their distinctive names, their construction being at once obvious on inspection. To those however, who are desirous to become acquainted with the more complicated instruments, and their use in the higher Mathematics, we beg to refer them to the work above noted, in this series, where a full description will be met with. The requisite instruments are, 1st, the drawing board: this should be at least 18 inches by 12 broad, made of good seasoned baywood, having cross pieces at the ends to prevent warping. 2nd, the drawing square: the blade must be equal in length to that of the board; one made with thumb-screw and moveable stock will be useful in drawing oblique lines. 3rd, parallel ruler: the wheel form is the best and most useful. 4th, compasses: two are requisite; one with a pencil leg, called "bow compasses," the other having a pen leg, for inking in the circles, &c.; a pair of small compasses, termed "spring dividers," would be of use in marking off minute divisions; for executing large diagrams a pair of large compasses with moveable leg will be requisite—pencil and pen legs will be necessary with this. 5th, "drawing pen:" lines of various thicknesses can be drawn by this, by merely turning the screw. 6th, pencils: a very good kind for general use is Foster's "phonographic" pencil. Cartridge paper will serve admirably for the initiatory lessons; it may be fastened on the board by "drawing pins," or by pieces of gummed paper, or even by wafers.

December, 1852. R. S. B.

THE ILLUSTRATED LONDON PRACTICAL GEOMETRY.

DEFINITIONS AND CONSTRUCTIONS.

A POINT is that which has no parts—such is the true mathematical definition; it is thus merely an idea, not apparent to our senses; but to perform an operation we must have something obvious to these; it has, therefore, been agreed upon to represent a mathematical point, which has merely position, by a physical one, which has comparative size, and is generally made by the point of a pencil, a pin or compass leg; the position from which a circle is described, as *a* fig. 14, is termed a point; also the place where two lines, *a*, *b*, fig. 1, intersect or cut one another; it is in this case generally called the point of intersection.

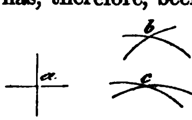


fig. 1.

A LINE is that which has length but not breadth, it has been defined as the "flowing of points." A geometrical line is therefore made by joining a succession of points, and this is done by placing the edge of a ruler to coincide with the points *a*, *b*, fig. 2, and drawing along it with a pencil or graver. A line is termed indefinite when it has no obvious termination, as *a*, *b*; finite when terminated by obvious marks, or supposed to have such, as *c*, *d*. A line is said to be produced when it is lengthened in the same direction; thus a line may only extend to *e*, fig. 2, but it may be produced to *d* or *c*. A circular line, *a*, *b*, fig. 3, is that which is continually changing its direction and described by compasses from one point, which is termed its centre, the line forming a circle is a completed circular line. A CURVED LINE, *e*, *d*, is that which

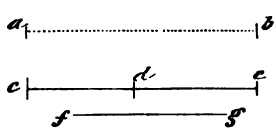


fig. 2.

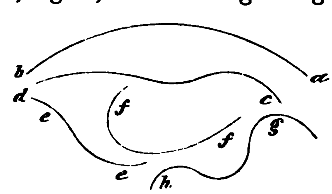


fig. 3.

is drawn in more than one direction. In geometrical drawing, lines are used in two ways, "apparent" or "determined" lines, as *a*, *b*, fig. 4,

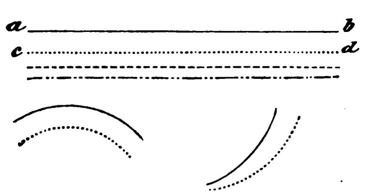


fig. 4.

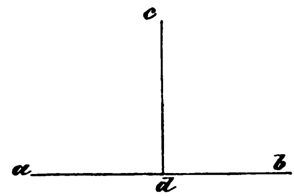


fig. 5.

and "occult" or "partial," as *c*, *d*. In general occult lines are shown in diagrams as only useful in constructing them, but meant, after the operation is performed, to be rubbed out, the determined lines being left in. A line is said to be PERPENDICULAR to another, as *a*, *b* to *c*, *d*, fig. 5, when the angles on each side of the upright line are equal to one another. A line is said to be VERTICAL as *c*, *d*, when it inclines neither to one side nor the other; it differs from a perpendicular line in the fact that it is always straight up, whereas a line may be perpendicular to another, and yet be itself much inclined,—thus a ship's mast may be both vertical and perpendicular to the deck, in time of complete calm, but if storms arise, and the vessel reels over to one side, the masts are no longer vertical, although still perpendicular to the deck; this distinction should be carefully noted. A HORIZONTAL line is that which is parallel to the horizon, or at right angles to a vertical line, *a*, *b*, is a horizontal line. Lines that are neither vertical or horizontal are said to be OBLIQUE, as *a*, *b*, *c*, and *d*, fig. 6. Lines that follow one another at equal distance, and which if produced ever so far both ways never meet, are called PARALLEL LINES, as *a b*, *c d*, *e f*, *g h*, fig. 7.

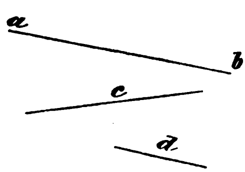


fig. 6.

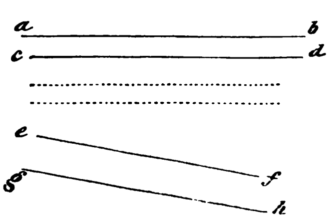


fig. 7.

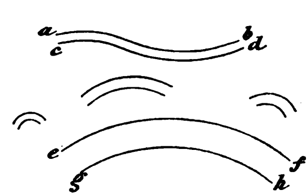


fig. 8.

Curved lines, as *a b c d*, fig. 8, may also be parallel, and circular lines, *e f*, *g h*; these are termed also concentric, as in fig. 86, are two CONCENTRIC circles. The SIDES of a figure, or the BOUNDARY lines, are those within which the figure is contained, as *a*, *b*, *c d*, fig. 13,

are the sides of the figure *a b c d*; the line *c, d,* is called the BASE, on which the figure rests or is constructed. Lines that incline towards one another, as *a b, c b,* figure 9, and if produced would meet in a point, are angular lines, and form an angle, as the angle *a b c, c b a;* when the lines are right or straight lines *a b c b,* the angle is RECTILINEAL, but if curved, or circular as *f g, h g,* it is a CURVILINEAR ANGLE. When a perpendicular line cuts another, as *a b, c b,* fig. 10, the angle formed at the point of intersection is called a RIGHT ANGLE. If an oblique line meets a horizontal one, the angle formed at the point of intersection is either an acute or an obtuse. An OBTUSE ANGLE, *a b c,* fig. 11, being greater than a right angle, or more than ninety degrees; an ACUTE ANGLE, fig. 12, less than a right angle.

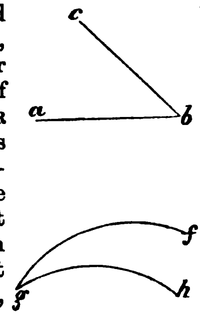


fig 9.

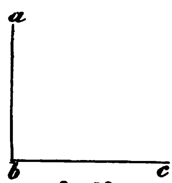


fig. 10.

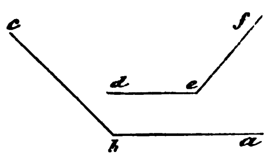


fig. 11.

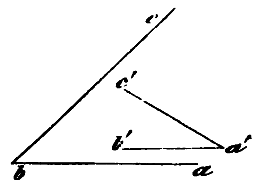


fig. 12.

A SUPERFICES, or SURFACE, is that which has length and breadth but not thickness, hence it is that which is formed by boundary lines, as *a b c d, e f g h,* fig. 13. A FIGURE is that which is contained by three, (fig. 19) or more (fig. 31) sides. A DIAGONAL is a line drawn across a figure, as *c b, f g,* fig. 13, joining opposite angles. Figures bounded by right lines are termed *rectilineal;* those by curved, *curvilineal.* A CIRCLE is drawn by placing one leg of the compasses in the centre, as *a,* fig. 14, and opening the compasses till the other leg reaches the point *b,* then cause this leg to revolve round the point *a* till it returns to itself; the distance by which the circle is de-

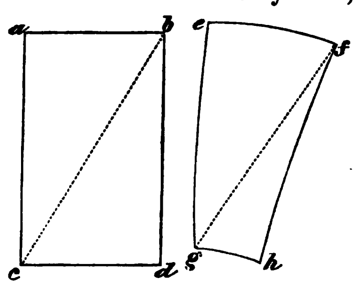


fig. 13.

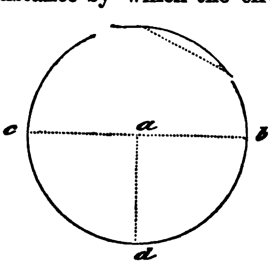


fig. 14.

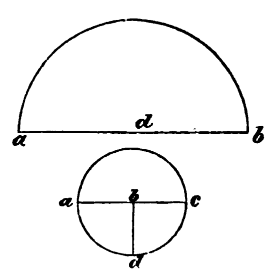


fig 15.

scribed, as *a b*, is called the RADIUS, and the DIAMETER, as *c a b*, is double the radius; the boundary line is called the CIRCUMFERENCE. There are 360° in a circle, 180° in a SEMICIRCLE, *a d b*, fig. 15, and 90° in a QUADRANT, as *c a b*, fig. 16. The semicircle is described from the centre *d*; the quadrant from *a*, two lines *a b*, *a c*, being first drawn at right angles to

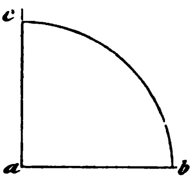


fig. 16.

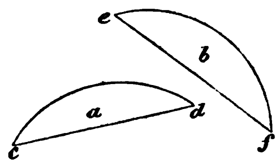


fig. 17.

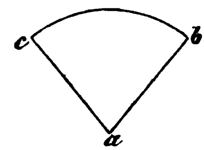


fig. 18.

one another. A SEGMENT, as *a*, *b*, fig. 17, is a portion of a circle contained by part of the circumference, and a straight line joining its extremities, as *c d*, *e f*; this straight line is called the chord, and an ARC is part of the circumference of a circle. A SECTOR is part of a circle bounded by two radii, or semi-diameters, as *a b*, *a c*, fig. 18, and part of a circumference.

An EQUILATERAL TRIANGLE is a right lined figure, having three equal sides, as fig. 19.

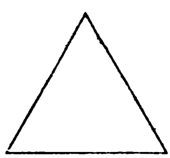
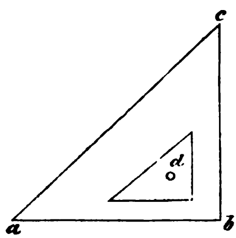


fig. 19.



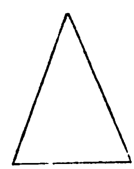


fig. 21.

fig. 20.

A RIGHT ANGLED TRIANGLE is that which has a right angle, as fig. 20; *a b* is called the base, *b c* the perpendicular, and *a c* the hypoteneuse.

An ISOSCELES TRIANGLE is that which has two equal sides, as fig. 21.

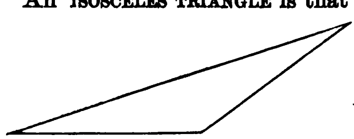


fig. 22.

An OBTUSE ANGLED TRIANGLE is that which has an angle greater than a right angle, as fig. 22.

A SCALENE TRIANGLE is that which has three unequal sides, as fig. 23.

A SQUARE is a figure contained within four equal sides, all the angles of which are right angles, as fig. 24.

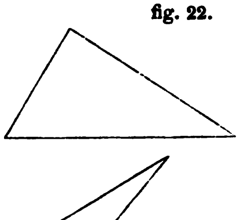


fig. 23.

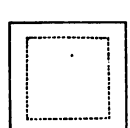


fig. 24.

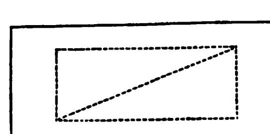


fig. 25.

A PARALLELOGRAM is a rectilineal figure, contained within four equal sides, two of which only are equal, as fig. 25.

A RHOMBOID is a quadrilateral, or parallelogram, but has no right angles, as fig. 26.

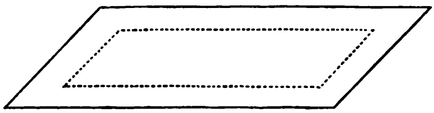


fig. 26.

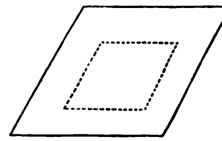


fig. 27.

A RHOMBUS is a quadrilateral, the sides of which are equal, but has no right angles, as fig. 27.

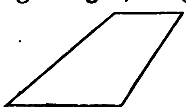


fig. 28.

A TRAPEZIUM is a quadrilateral, the opposite sides of which are neither equal or parallel, as fig. 28.

A TRAPEZOID is a quadrilateral, none of its sides being equal, but two parallel, as *a b c d*, fig. 29.

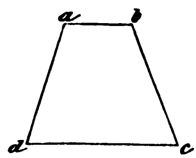


fig. 29.

A PENTAGON, *a e d c b*, is that which has five sides,

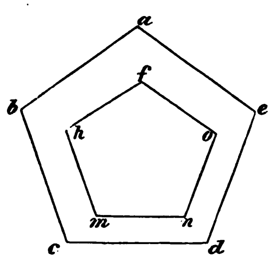


fig. 30.

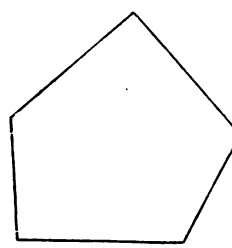


fig. 31.

it is of two kinds, equal sided and angled, as fig. 30, and irregular, as fig. 31.

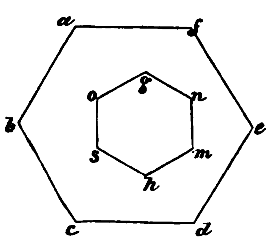


fig. 32.

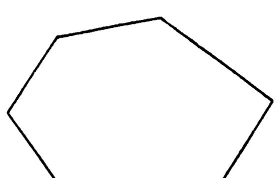


fig. 33.

A HEXAGON is a figure having six sides, *a f e d c b*, it is of two kinds, equilateral and equiangular, as fig. 32, and irregular, as fig. 33.

A HEPTAGON is a figure having seven sides, it is also of two kinds, regular, as fig. 34, and irregular, as fig. 35.

An OCTAGON is that which has eight sides, it is of two kinds, regular

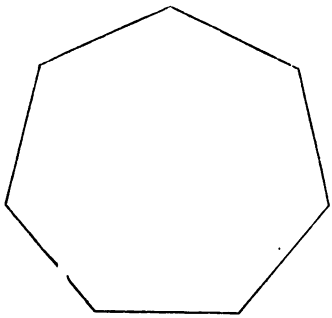


fig. 34.

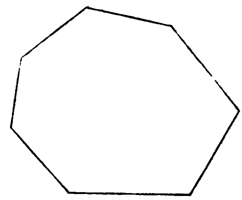


fig. 35.

and irregular; fig. 36 is a re-gular octagon.

A NONAGON is that which has nine sides; fig. 37 is an equal sided nonagon.

A DECAGON has ten sides; fig. 38 is an equal sided decagon.

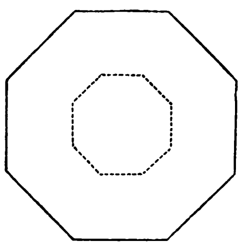


fig. 36.

An ELLIPSE, or OVAL, as it is more popularly termed, is produced by the section of a cone, *a c b*, by a line *d e*, not parallel, that is oblique, to its base, as shown in fig. 39. The largest diameter, as *a b*, fig. 40, is called the "transverse diameter," or "axis;" the shortest, *c d*, the "conjugate." The two centres, *e f*, are termed the "foci," they are placed in the transverse diameter, at an equal distance from the conjugate. The "centre" of the ellipse is at the point of intersection of the two diameters. All lines drawn

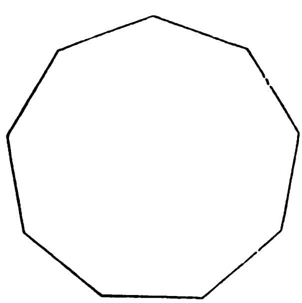


fig. 37.

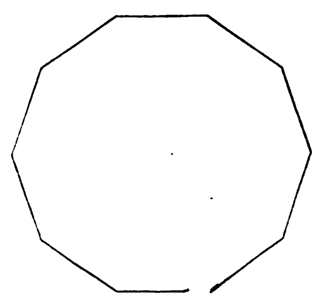


fig. 38.

within the ellipse, parallel to one another, and bisected by a diameter, are called ORDINATES to that diameter which bisects them, as *h h*. The point where the diameters touch the circumference or boundary line of the ellipse, is called the "vertex." When the transverse diameter, as *a b*, is cut into any two parts by an ordinate, as *e*, the parts, *a e*, *a g*, are called "abscissa."

A PARABOLA is the plane of a section of a cone, *a b c*, cut by a line, *d e*, parallel to one of its sides, as shewn by fig. 41. A line, *a b'*, fig. 42,

through the middle, is called its "axis," *c a d* the "directrix," *e* is the "vertex;" all lines, as *f f*, that cut the axis at right angles are

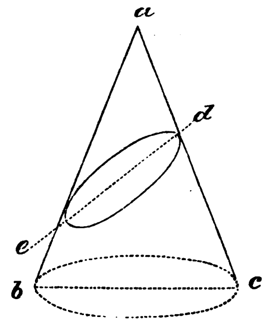


fig. 39.

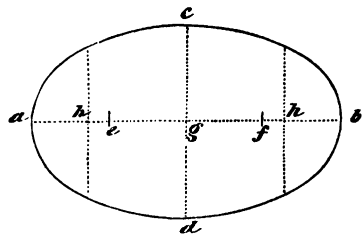


fig. 40.

called "ordinates;" the greatest ordinate, as *b b*, limiting the length of the parabola, is called the "base;" right lines drawn within a

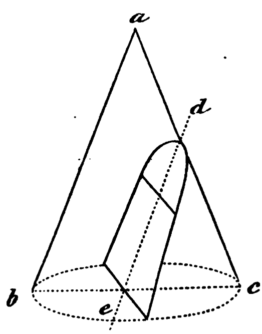


fig. 41.

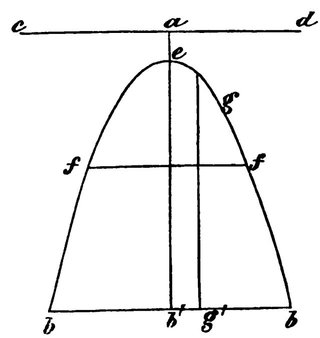


fig. 42.

parabola parallel to its axis, as *g'*, are called "diameters;" the ordinate drawn through the focus is called the "parameter;" the abscissa is that part contained within the vertex and the ordinate, *b b*, which limits its length, as *e b'*.

The HYPERBOLA is a figure formed by the plane of a section of a cone, *c b d*, fig. 43, by a line either parallel to its axis, as *g*, or otherwise as *e a*, so that if the cutting line be produced through one side of the cone, as at *o*, it may meet the other side of the cone, if it be produced beyond the vertex *b*, as to *a*. The figure *h n o n m* is a hyperbola. The line *o g* drawn through the middle is called the "axis," that part of it as *o a*, which is produced till it meet the other side of the cone produced, is called the "transverse diameter." Ordinates are lines drawn within

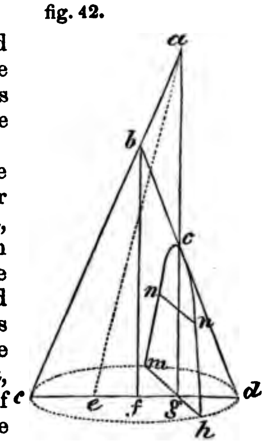


fig. 43.

the figure at right angles to the axis, as *n n*; that ordinate passing through the focus is the "parameter," the middle point of the transverse diameter is called the centre of the hyperbola—from this point lines can be drawn, which will approach nearer and nearer to the sides of the hyperbola, yet never really meet, however far the curve lines be produced, lines thus drawn are termed "assymptotes."

The CONJUGATE AXIS is a line drawn through the centre of the hyperbola, terminated by a circle, drawn from the vertex of the curve; the radius of this circle being the distance between the centre and focus of the ellipse. The assymptotes are drawn from the centre through the terminations of the conjugate axis.

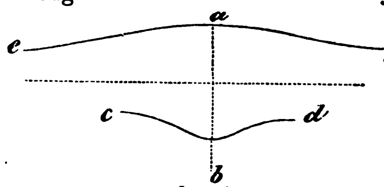


fig. 44.

The CONCHOID, a conic section or curve, discovered by Nicomedes, about the year A.D. 450, the properties of which will be hereafter described; in figure 44, which represents the curve, *a b* is the centre line, *f e* the "superior conchoid," and *d c* the "inferior conchoid."

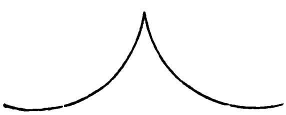


fig. 45.

The CISSOID, another curve or conic section, shewn in fig. 45, it was discovered by Diocles, a mathematician, who flourished about A.D. 150.

The CYCLOID—a curve, generated in the following manner:—Let *a b*, fig. 46, be a straight line, along which the circle *c d* rolls as a cart wheel does along a road; if the distance, *a b*, is equal to the distance which the circle rolls over in one revolution, or in other words, equal to its circumference, the point *c* will trace out the curve, as shown in the diagram.

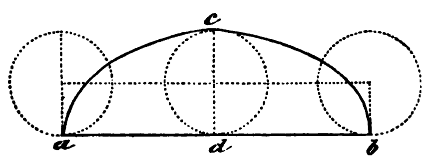


fig. 46.

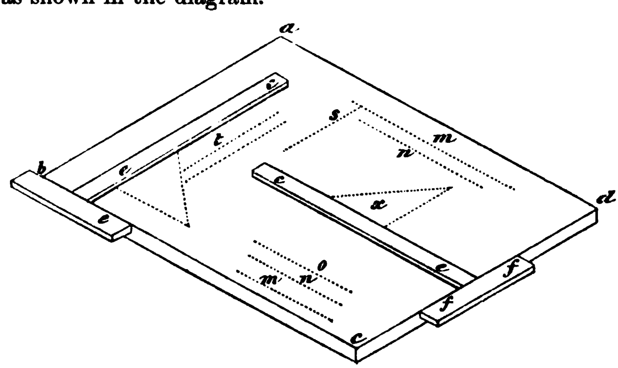


fig. 47.

In fig. 47 we give a representation of the drawing board, ***a b c d***; the square is *e e f f*. Fig. 48 shews the two forms of parallel rulers. Figs. 61 and 62 are various forms of scales. Fig. 64 is a "diagonal scale:" and fig. 65 a "protractor." These we shall more fully describe hereafter.

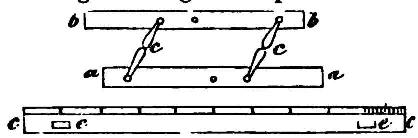


fig. 48.

PROBLEMS.

To draw a right line parallel to another, at a given distance.— Let *f, e*, fig. 49, be the line, and *d* the distance. With the distance *d* in

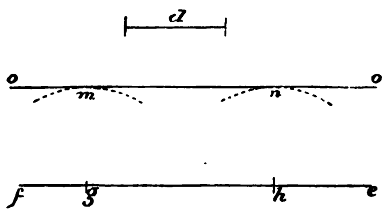


fig. 49.

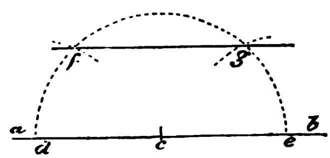


fig. 50.

the compasses as radius, from any two points, as *g, h* in the line *f e*, describe arcs at *m n*; touching these draw a line *o o*, it is parallel to *e f*. *Meth. 2nd*, Let *a b*, fig. 50, be the line, another parallel to it may be drawn at any distance as follows: from any point *c* with any radius describe a semicircle, from the points where it cuts *a b*, at *d, e*, with same distance cut the semicircle in *f, g*; through these points draw the desired line. *Meth. 3rd.* Let *a b*, fig 51, be the line, and *c* a point above it, through which it is desired to draw a line parallel to it. From any point, *d*, draw a line to *c*; with *c d* as radius from *c, d*, describe arcs; from *d* and *e* with distance *e c*, cut the arcs in *f* and *c*; through the points thus obtained draw *c f*—it is parallel to *a b*. *Meth. 4th.* Let *a b*, fig. 52, be two points through which it is desired to draw two lines parallel to each other. Draw a line *b c* through the point *b*; from *a* describe an arc touching *b c*; from *b* with same radius, describe another arc, *e*; through *a* draw a line, *a e*, touching the arc *e*—*a e* is parallel to *b c*.

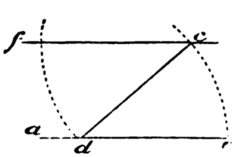


fig. 51.

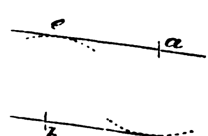


fig. 52.

To draw a line perpendicular to another at a given point.—Let $b\ a\ c$, fig. 53, be the line, and a the point. From a with any

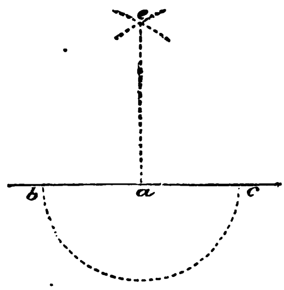


fig. 53.

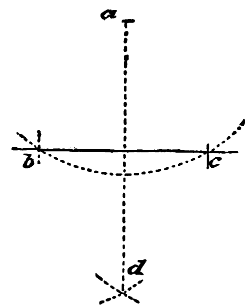


fig. 54.

radius describe a semicircle cutting the line in b and c; from c, b with radius $b\ c$, describe arcs cutting in e; join $a\ e$ it is perpendicular to $b\ c$. *Meth. 2nd.* When the point is above the line.—Let $b\ c$, fig. 54, be the line, and a the point; from a with any radius describe an arc cutting $b\ c$, in b, c, in these points with same distance, describe arcs cutting in d, draw $a\ d$. *Meth. 3rd.*—When the point is at the end of the line.—Let a, fig. 55, be the point, and $a\ b$ the line; take any point c above the line, with $c\ a$ describe part of a circle; from b through c draw a line to e, where this line cuts the circle draw to a. *Meth. 4th.*—Let $a\ b$, fig. 56, be the line, and b the point: from b with any radius as $b\ c$ describe the arc $c\ e$; from c with same distance lay off to f and e; from these points as centres, with same radius still in the com-

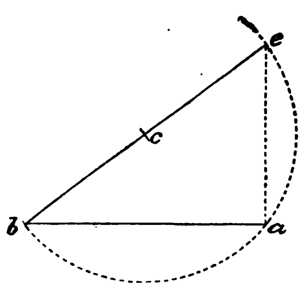


fig. 55.

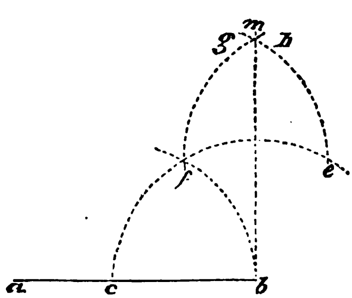


fig. 56.

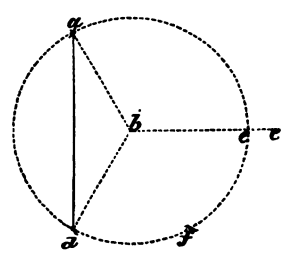


fig. 57.

passes, describe arcs *e g*, *f h*, cutting in *m*—draw *b m*. *Meth. 5th.* WHEN THE POINT IS BEYOND THE LINE.—Let *b c*, fig. 57, be the line, and *a* the point; from *b* as centre with *b a*, describe the circle *a f e*; from *e* with *a b* cut this in *f*, and from *f* to *d*; join *a d*—it is perpendicular to *b c*.

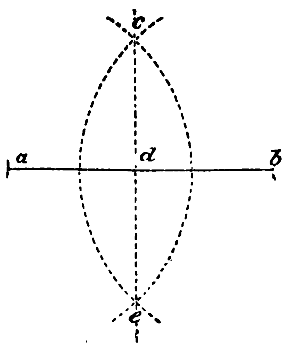


fig. 58.

TO BISECT A RIGHT LINE, THAT IS, TO CUT IT INTO TWO EQUAL PARTS.—Let *a b*, fig. 58, be the line; from *a b* with any radius describe arcs cutting in points *c*, *e* above and below the line, through these draw a line *c d e*; *d* is the "point of bisection."*

TO DIVIDE A GIVEN LINE INTO ANY NUMBER OF EQUAL PARTS.—Let *a b*, fig. 59, be the line; from *a* and *b*, with *a b*, describe arcs *a c*, *b d*; from *a b*, with any distance cut these in *c*, *d*, from *a*, *b*, draw through *c d*, indefinite lines *a b*, *b* 6; these will be parallel to one another but oblique to *a b*. From *a*, *b*, divide the lines into any number of equal parts, always one less than *a b* is to be divided into, as 6 in the diagram; join the points 1, 6, 2, 5, &c.—these lines will mark the points of division on *a b*.

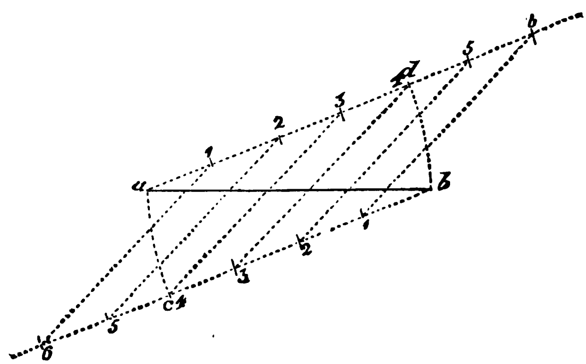


fig. 59.

TO CUT OFF FROM A CIRCLE TWO EQUAL SEGMENTS.—Let *h g c*, fig. 60, be the circle; draw the diameter *a d b*; from its centre *d* draw *d f* perpendicular to *a b*; join *f a*, *f b*, *a h f*, *f g b* are the segments. The division of lines is of use in the construction of *scales*. The first we shall notice is

* The radius of the arcs must be greater than half the line to be bisected.—See fig. 82.

that of feet and inches. There are 12 inches in 1 foot: suppose then that any distance is assumed to represent a foot, and this be divided into twelve equal parts, each of these will be an inch; and the longer distance may be multiplied to any extent to denote the number of feet required in the scale. If half an inch is taken as the representative of a foot, then the scale is denoted as "half inch to the foot," and so on. In making a scale, a line, as *a b*, fig. 61, is drawn, and the assumed distance laid on it any number of times, as 7 in the drawing. The division to the left hand is generally used to denote the space of "inches," it is therefore divided into twelve parts; in the figure we have only shown it divided into two; *c* denoting the position of the 6th inch. The line *d e* is divided so as to make a scale of an inch to the foot—the inch division is fully marked out. In fig. 62 the method of drawing "scales" is shown, the lowest is a scale of ten feet—this is used in architectural plans and surveys. Suppose a line is to be divided for the purpose of making a scale, as *a b*, fig. 63; from *a* with a distance as near half *a b* as the eye can judge, lay off to *d*, by sweeping the other leg round towards *b*, it is found to reach to *e*; the distance *b e* is therefore the measure of the excess of the distance obtained over the actual line to be divided. If then *b e* is bisected, and half of it carried from *d* to *g*, *g* will be found to divide *a b* into two equal parts. To divide a line, as *h m*, into an equal number of parts, as 4, it will be quickest done by dividing it by Problem in fig. 58, till the point is found as the point *o*, dividing it into two parts, then these divisions, as *h o*, *o m*, into two other parts. To take a distance from a scale: suppose it is 4 feet, on the point marked 4, on the line *a b*, fig. 61, reach to 0; suppose it 4 feet 6 inches, from 4 reach to *c*, the division denoting the 6th inch.

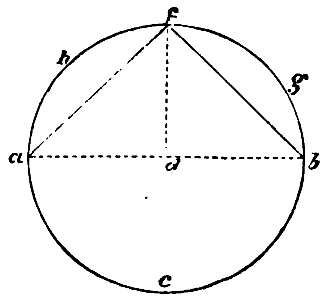


fig. 60.

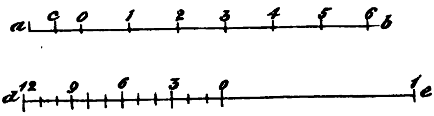


fig. 61.

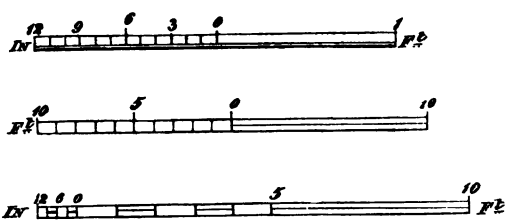


fig. 62.

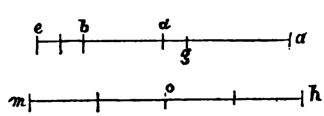


fig. 63.

TO CONSTRUCT A DIAGONAL SCALE FOR MEASURING LARGE DISTANCES.—Draw the line *c* 2, fig. 64, and divide it into any number of equal parts,

as three; for use the division should be eleven in number; divide the last division to the right hand into ten equal parts; from *c* draw *c d* perpendicular and equal to this, and divide it into the same number of equal parts; number these as at 2, 4, &c., these denoting 20, 40, &c.; the intermediate ones, 30, 50, &c. From *d* draw *d e* parallel to 2 *c*; from

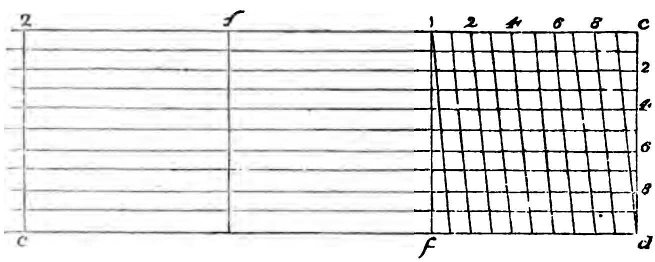


fig. 64.

the points in *c d*, draw lines parallel to *d e*; through the large division in 2 *c* draw lines parallel to *c d*. Divide *d f* into ten parts, and from these draw to the division on *c* 2, as in the drawing. To measure distances from this scale proceed as follows: suppose the distance to be taken is 250; with compass point in the large division 2, open to the point 5 in the division to the right hand—to measure 165; with point of compass in one, lay off to division 6; then with point in this, bring down the leg in 1 to the 5th horizontal division, then move the point from 6 to the same division. In this scale the distances may have different values; thus, the large divisions may be ten, while the small ones will be each one, or the large one hundred, and the small tens, or the large a thousand and the small ones hundreds.

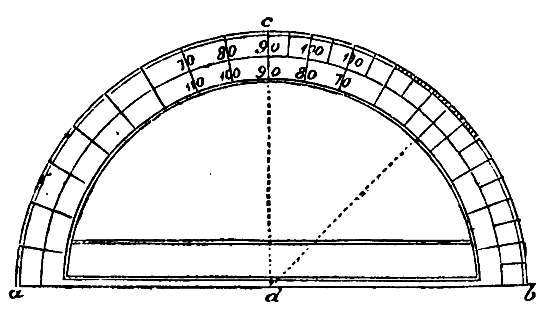


fig. 65.

To BISECT A GIVEN ANGLE.—Let *a b c*, fig. 66, be the angle, from the apex *a*, with any radius, describe an arc *b e c*; from *b* and *c*, with same radius, describe arcs cutting in *d*; join *a d*, it is the line of bisection.

AN ANGLE BEING GIVEN, TO DRAW ANOTHER SIMILAR TO IT.—Let *d b c*, fig. 67, be the angle; draw a line *c d;* from *b* with any radius, describe an arc *h g;* from *c*, with same radius, describe, *h n;* measure from *h* to *g*, where the line *b c* cuts the arc *g h;* lay this distance from *h* to *n*, from *c* through *n* draw a line *c n*—*d c n* is equal to *d b c*.

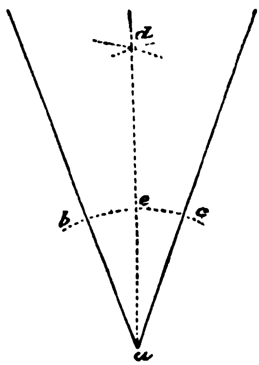


fig. 66.

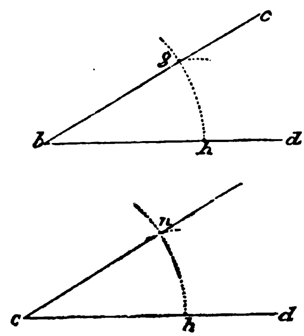


fig. 67.

TO BISECT A QUADRANT OF A CIRCLE.—From *a*, *b*, fig. 68, with radius greater than half of the arc *a b*, describe arcs cutting in *d*, *c;* join *c d;* where this line cuts *a b* is the point of bisection.

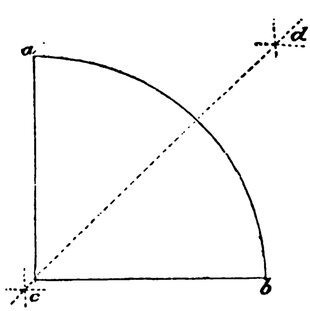


fig. 68.

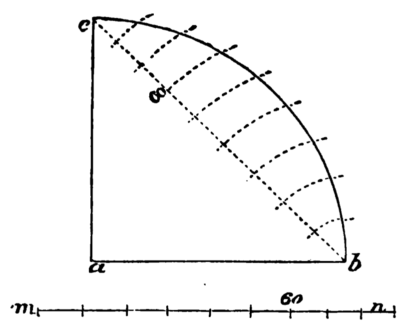


fig. 69.

TO CONSTRUCT A SCALE OF CHORDS, BY WHICH ANGLES MAY BE MEASURED AND LAID DOWN.—Draw *a b*, *a c*, fig. 69, at right angles; from *a*, with any radius, describe the quadrant *b c;* divide *b c* into nine equal parts; join *b c;* from *b* transfer the divisions in *b c* to this line. Each of these divisions comprise ten degrees, and the chord of 60° is equal to the radius *a b*. The distances on *b c* may be transferred to a straight line, for the convenience of use, as *m n*. Angles are also measured and laid down by means of an instrument called the "protractor." It may

be readily constructed of card-board, or thin veneer; draw any line *a b*, fig. 65, from *d* describe a semicircle, and draw *d c* at right angles to *a b*; divide the quadrants into nine equal parts, each comprising ten degrees, thus making 180° in the semicircle. From *d* draw lines through these points, the position of the tenth division will be thus marked; by dividing each of these into ten parts the positions of the degrees will be given. An inspection of the drawing will explain the method of construction.

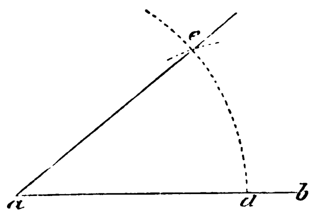


fig. 70.

TO CONSTRUCT AN ANGLE LESS THAN 90° BY MEANS OF THE SCALE OF CHORDS.—Draw any line *a b*, fig. 70; from *a*, with the chord of 60° as radius, describe an arc *d e*; suppose the angle is to be 40°, take this distance from the scale of chords, and from *d* cut the arc in *e*, from *a* draw *a e*; *a e* is at an angle of 40° to *a b*.

TO MEASURE A GIVEN ANGLE.—Let *a b c*, fig. 70, be the angle; from *a* with chord of 60° describe an arc *d e*; from *d* measure to *e*, where the angular line cuts the arc; measure this distance on the scale of chords; this point gives the angle.

TO CONSTRUCT AN ANGLE GREATER THAN 90°.—Draw any line, *a b*, fig. 71; from *a* with a radius of 60°, describe the arc *d f*; suppose the angle to be 110°, take any angle less than 90° from this, as 60°, and lay it off from *d* to *e*; the difference of 60° and 110° being 50°, lay this angle from *e* to *f*; join *a f*; it is at an angle of 110° to *a b*. NOTE.—It is essentially necessary that the distances of the angles be taken from the same scale as the radius or chord of 60° is taken from.

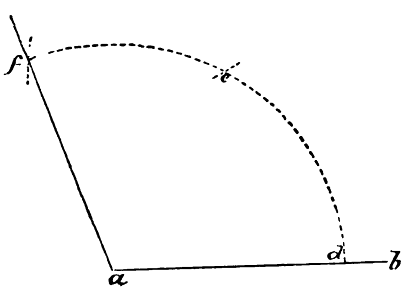


fig. 71.

TO CONSTRUCT AN ANGLE BY MEANS OF THE "PROTRACTOR."—Let *a b*, fig. 72, be the line on which an angle of say 45° is to be constructed; make the base of the protractor coincide with the line *a b*, and the central point *d*, fig. 65, with the point *e*, from whence the angle is to be made; mark on the paper the position of the point of 45° on the periphery, or outside of the protractor; from *e* draw a line through this point; it will be at an angle of 45° with *a b*; the point *c* denotes the position of the angle laid down. In like manner, an angle greater than

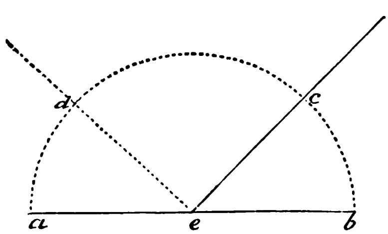


fig. 72.

90° may be laid down, by placing the protractor properly, and marking the position of the point of the angle, which will be found in the left hand side of the protractor. Angles may also be measured by producing the line if necessary, so that it may reach beyond the periphery of the protractor, when the base is made to coincide with the base line of the angle. If the central point of the protractor coincides with the point from whence the angular line begins, the point where it cuts the edge of the protractor denotes the angle.

A GIVEN LINE CUT INTO SEVERAL PARTS TO DRAW ANOTHER LINE CUT IN THE SAME PROPORTION.—Let *a b*, fig. 73, be the line, and *c*, *d*, *e*, the points where it is cut, and *g h* the line to be cut. Join *g h* to *a b*, making any angle, as *a m*; join *m b*; parallel to this, through *c d e*, draw lines to *o s t*—these are the points, cutting *a m* equal to *g h*.

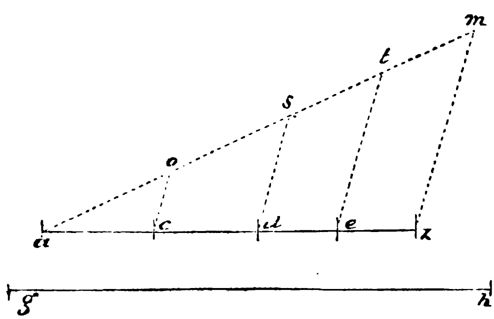


fig. 73.

TWO LINES BEING GIVEN TO FIND A THIRD PROPORTIONAL.—Let *a b*, fig. 74, be the two lines. Draw any line, *c d*, equal in length to *a b*, joined; from *c* draw a line *c f* at any angle to *c d*, make *c g*=*c e* or *a*, join *g e*; parallel to this, from *d*, draw *d f*—*f g* is the third proportional.

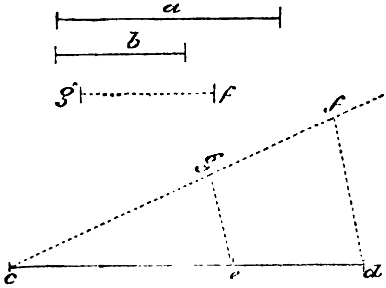


fig. 74.

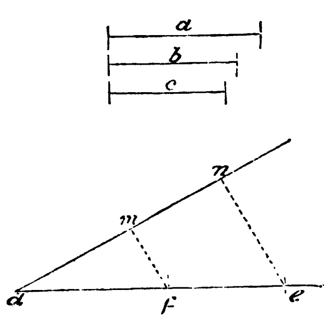


fig. 75.

Three lines being given to find a fourth proportional.—Let a b c, fig. 75, be the lines. Draw any line, d e, with a from d; cut it in f, and from same point with b cut a line d n, drawn at any angle to d e in m; join m f; from f with c cut d e in e; from e draw to n parallel to m f—m n is a fourth proportional to a b c.

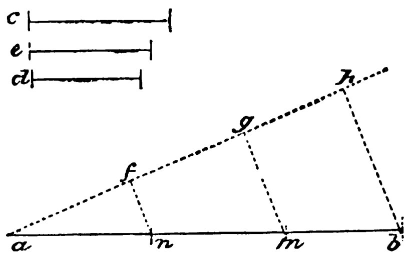


fig. 76.

To cut a given line so that the divisions will be in proportion to lines of a certain length each.—Let a b, fig. 76, be the line; and c d e the lengths. Draw a h at any angle to a b; from a, with distance c, cut a h in f; with d from f cut a h in g; and with e from g in h. Join h b; parallel to this, from f g, draw lines to m n—a b is cut in these points as required.

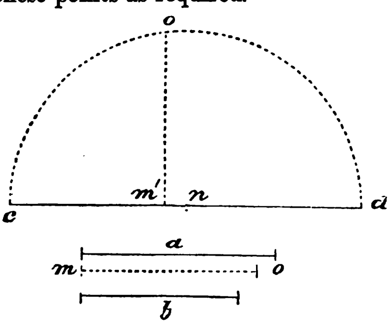


fig. 77.

Two lines being given, to find a mean proportional.—Let a b, fig. 77, be the lines. Draw any line, c d, from d, with distance a, cut c d in m'; from m', with b, cut it in c; bisect c d in n, from n, with n c, draw a semicircle d o c; from m', draw to o perpendicular to c d—m', o is the mean proportional between a b.

To divide a line into extreme and mean ratio.—Let a b, fig. 78, be the line; at the point b, with half a b, erect a perpendicular b c; from c, with b c, describe a circle; from a, through c, draw a c; from a measure to d, where the circle cuts a e, and lay it off from a to n. The line a b is divided at this point into mean and extreme ratio,—that is, the largest half, as a n, is a mean proportional between the shortest part n b and the whole line a b.

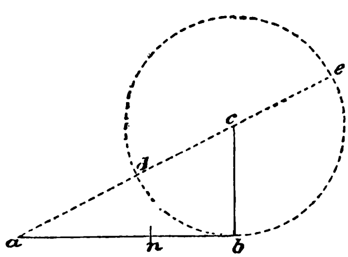


fig. 78.

A line being given representing the sum of two lines, of which a mean proportional is also given, it is required to find the point which divides the line into two unequal lengths.—Let a b, fig. 79, be the line, and c the mean proportional; bisect a b in d, and from d,

with $d\,b$, describe a semicircle; from a erect a perpendicular to $n = c$; from n draw to m parallel to $a\,b$; from m drop a perpendicular to e—$a\,e$, and $e\,b$, are the length of the lines, of which c is a mean proportional.

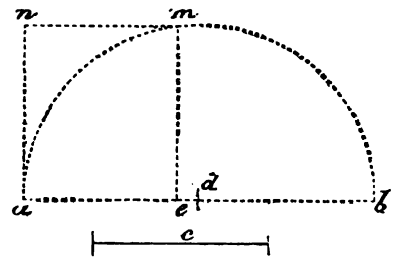


fig. 79.

TWO POINTS BEING GIVEN, TO FIND TWO OTHER POINTS EXACTLY INTERPOSED, SO THAT A RULE TOO SHORT TO REACH BETWEEN THE ORIGINAL POINTS MAY BE USED TO DRAW A LINE BY MEANS OF THE POINTS FOUND.—Let $a\,b$, fig. 81, be the points. From these, with any radius, describe arcs cutting in $c\,d$; from $c\,d$, with radius $c\,d$, describe arcs cutting in $g\,h$; a line may be drawn from a to g, from g to h, and so on; thus drawing it, as if it had been done between the points a and b at once.

TWO LINES GIVEN TO DIVIDE THEM, THAT THE PARTS WILL BE PROPORTIONAL TO ONE ANOTHER. —Let $a\,b$, $c\,d$, fig. 80, be the lines. Draw $d\,e = a\,b$, and at right angles to $d\,e$, draw to $f = c\,d$; join $e\,f$—bisect de in g, and describe the semicircle; from h, where $e\,f$ cuts the circle, draw to n, cutting $d\,f$; draw $h\,m$ parallel to $d\,f$; transfer $e\,m$ to $a\,b$ from a to o, and $m\,h$ from c to t.

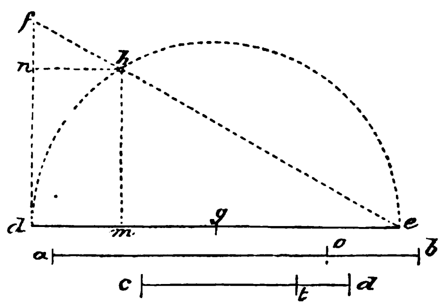


fig. 80.

TWO LINES CONVERGING TO A POINT NOT GIVEN, TO DRAW OTHER LINES CONVERGING TO THE SAME POINT.—Let $a\,b\,c$, fig. 83, be the lines; draw any parallel lines as $e\,f$, $g\,h\,m\,n$, take the distance $h\,h$, and lay it on $e\,f$ to $e\,f$; also $i\,i$ to $g\,h$, and $o\,s$ to $m\,n$; through $m\,g\,e$, $n\,h\,f$, draw lines. In nearly the same way may a given line be cut into divisions similar to a given line, Let $a\,b$, fig. 82, be the line, cut into divisions as shown; $c\,d$ may be cut similarly; $c\,d$ must be parallel to $a\,b$; from $b\,a$ draw lines at any angle meeting in f; to this point, from the various parts of division, on $a\,b$, draw lines; these will cut $c\,d$, as desired.

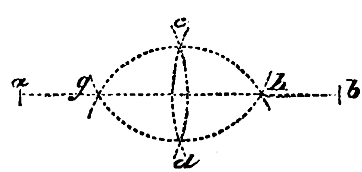


fig. 81.

Through a given point to draw a line, which will be a tangent to a circle.—Let *a b c*, fig. 84, be the circle, and *d* the point; from the centre of the circle *a* draw a line to *d*; bisect this in *e*; from *e* describe a semicircle with radius *e d*; through the point where this cuts the circle, as *b*, draw from *d*—*d b* is the tangent. *Meth. 2nd.*—Let *a b c*. fig. 85, be the circle, and *c* the point through which the tangent is to be drawn; from *a* draw *a e*; through *c* draw *e c d*, at right angles to *a e*; *e e d* is the tangent.

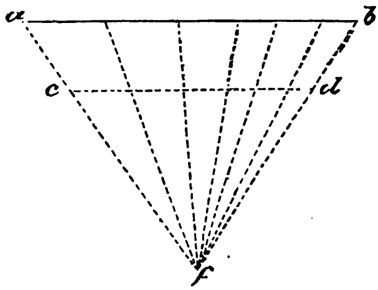


fig. 82.

A circle and its tangent being given, to find the exact point of contact.—Let *d b c*, fig. 87, be the circle, and *e c d* its tangent; from *a*, the centre, drop a perpendicular, *a c f*—the intersection *c* will be the point.

A point without a circle being given, to draw a tangent through the point.—Let *a b c*, fig. 86, be the circle, and *d* the point; join *a d*; from the point *b*, where it intersects the circle, draw a tangent, as *b f*; from *a*, with radius *a d*, describe a circle, *d f h*; from *f* make *f h*=*f d* join *h d*—it is the tangent required. In the

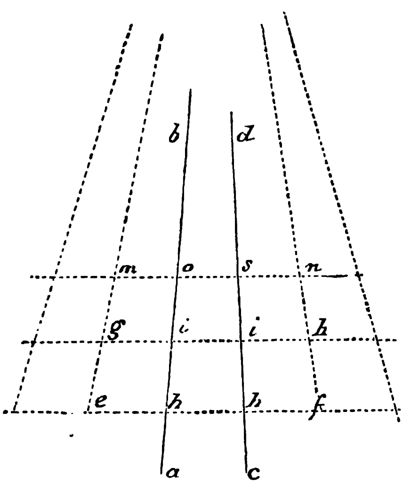


fig. 83.

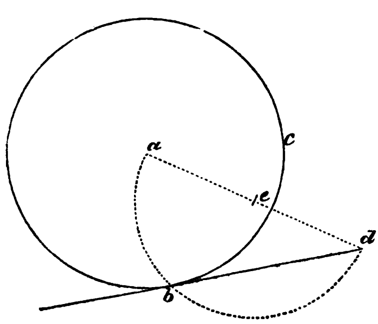


fig. 84.

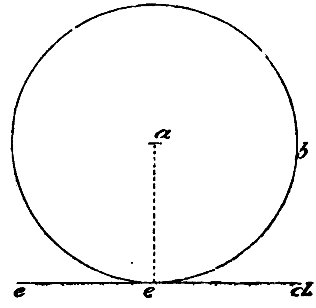


fig. 85,

preceding problems we have assumed the centres of the circles to have been given; in practice this may not always be the case, we therefore give methods of finding the centres of circles.

To find the centre of a given circle.—Let *a b c*, fig. 88, be a circle, of which the centre is required; draw any line *a b*, terminated by the circumference; bisect it in *g*, and draw *d c* at right angles to *a b*; bisect *c d* in *f*; and draw *f e* at right angles to *c d*; the point *f*, where they intersect, is the centre of the circle.

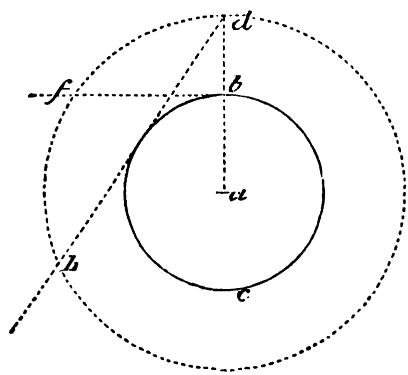


fig. 85.

Part of the circumference of a circle being given, to find the centre from which the remainder may be described.—Let *a b c*, fig. 89, be the part given, and *a b c* any three points therein; from *a* and *b*, with radius *a b*, describe arcs cutting in *d e*; and from *b* c, with *b c*, arcs cutting in *g h*; through these draw lines cutting in *m*, it is the centre required.

Three points not in a straight line being given, to find a point which will be the centre of a circle passing through the points.—Let *a b c*, fig. 90, be the points; from the points, as centres, with radius less than the distance between them, describe circles cutting in *e f*, *g d*; through these draw lines cutting in *m*—it is the point required. *Meth. 2nd* When the points are at a distance from each other, as *a b e*, fig. 91, join them by lines, bisect these in *d*, *c*; from these points erect perpendiculars cutting in *g*—it is the centre required. In cases where the points are nearly in a straight line, thus throwing the centre at such a distance from them that it will be difficult to describe the circle with compasses, the circumference may be described by the following means:—Place two thin rulers, *a b*, *b c*, fig. 93, their edges coinciding with the points; pass a

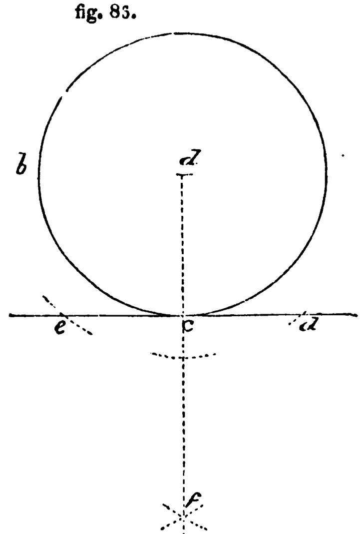


fig. 87.

pin through both to the point *b*, on which they may freely move; they must be restrained at this angle by a cross piece fastened to both; fix a pencil at the angle *b*, move the ruler so that their edges will always coincide with *a* and *c*, the pin or pencil at *b* will trace the circle. If the whole circle is to be described, the legs *a b*, *b c*, must be of considerable

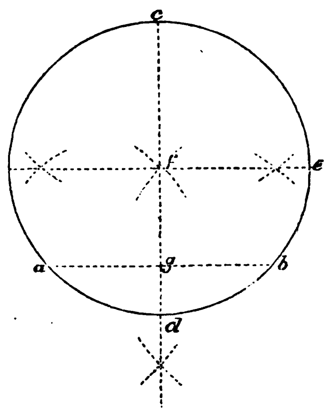


fig. 88.

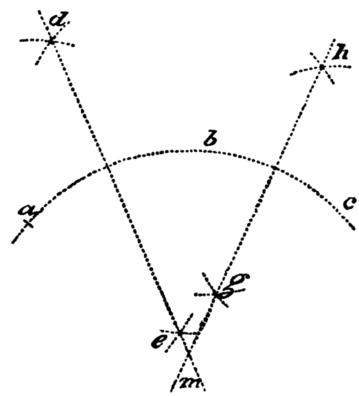


fig. 89.

length. *Meth. 3rd.* Points may be found through which to trace a circle, which will pass through three given points, as *a b c*, fig. 92. From *a*, through *b c*, draw lines produced to *d e*; from *a*, with any radius, describe part of a circle, as *d e*; from *e* with *d e*, lay off on this to *g*, and so on; from these points draw to *a*; from point *c*, with dis-

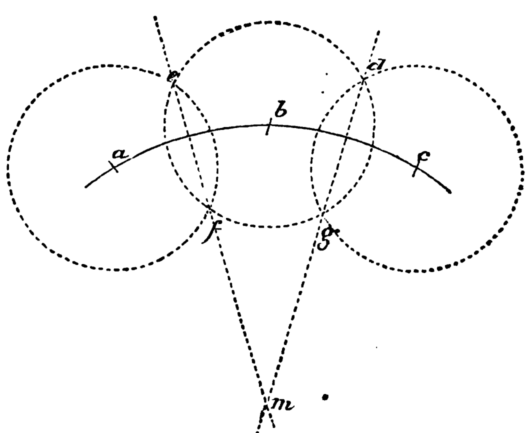


fig. 90.

tance *b c*, cut *g a* in *g*; from *g*, *a h* in *h*, from *h*, the other line from *a*—these are all points in the circumference of a circle, which will pass through *a b c*.

Having shown the various methods of drawing lines parallel, &c., by means of construction we now explain how these operations can be most rapidly affected, greatly facilitating complex constructions by means of the drawing board and square. The former is shown in fig. 47, *a b c d;* the edges are perfectly straight and even, those at the ends being at right angles to those of the sides, and *vice versa*. A convenient size for ordinary geometrical construction will be 16 inches long by 12 wide, $\frac{3}{4}$-inch thick; having cross pieces at the sides, to prevent warping. The form of the T square is seen in fig. 47, at *e e*, and is too well known to need further description; the blade *e e* should be as long as the length of the drawing board. The square can be moved along the edges of the board without altering its position; this is effected by having a ledge on each side of the blade. All lines, as *m n o*, drawn parallel to the sides, *a d*, *b c*, are at right angles to the ends *b a*, *c d*, while those parallel to the end *s*, as *t s*, are at right angles to the sides—hence arises a simple method of drawing lines parallel to one another. Thus, as the blade *e e* of the square is at right angles to the stock *f f*, it follows that if the blade is placed to have its edges parallel to the sides of the board, all lines drawn along it are not only parallel to the sides, but to one another, as *m n o;* if a line is to be drawn perpendicular to one of these lines, all that is required is to move the square into the position shown at at *e e*, *e*, the blade will then be parallel to the ends, consequently, lines drawn along its edge, as *s t*, will be at right angles to those previously

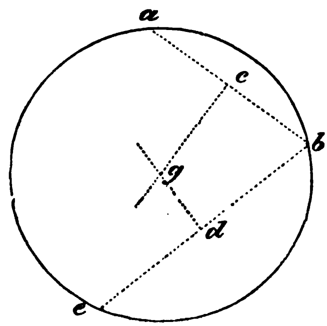


fig. 91.

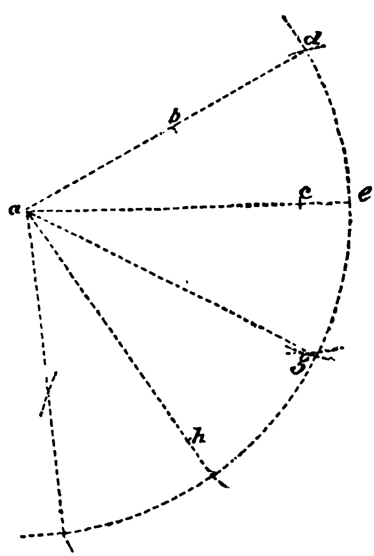


fig. 92.

drawn, as *m n o*. Again, by placing the edge of the blade to coincide with the points from which lines are to be drawn, either parallel or perpendicular to each other, lines can be drawn as required. It is obvious, however, that when right lines are required to be drawn changed in their direction, it is necessary to move the square at each time; to obviate this, a simple contrivance shown in fig. 20 is used; it is made of thin mahogany, its side *a b* at right angles to *b c*—hence, if the side *a b* coincides or lies in contact with the edge of the drawing square, all lines drawn along *b c* will be at right angles to the edge—the side *b c* must coincide with the point from which the perpendicular is to be drawn.

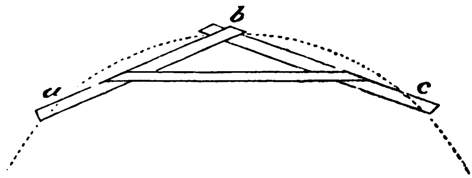


fig. 93.

In fig. 47, *x* shows the position of this simple instrument. The pupil will at once see the ease and rapidity with which lines can be drawn and figures constructed by the use of these contrivances. We shall now resume our problems—first noticing the various geometrical plane figures, and their modes of construction.

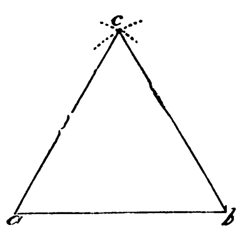


fig. 94.

To construct an equilateral triangle.—Let *a b*, fig. 94, be the length of its side; from *a b*, with *a b*, describe arcs cutting *d* in *c*, join *a c*, *b c*—*a b c* is the triangle.

To construct an isosceles triangle, the length of the base and one of the sides being given.—Let *a b* be the base, and *c d* the side; draw *e f*, fig. 95=*a b*, from *e f* with *c d*, describe arcs cutting in *g*—join *e g*, *f g*—*e f g* is the triangle required.

To construct a right-angled triangle, having the base and perpendicular given.—Let *a b*, fig. 96, be the base, and *c d* the perpen-

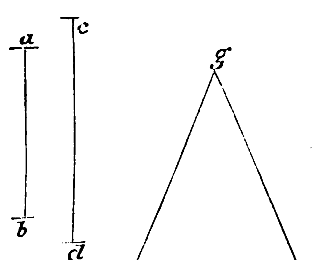


fig. 95.

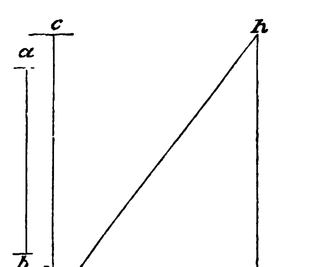


fig. 96.

dicular; draw $e\,f$ and make $e\,g = a\,b$; draw from g an indefinite line perpendicular to $e\,g$; with $c\,d$ from g, cut $g\,h$ in h—join $e\,h$.

TO CONSTRUCT AN OBTUSE ANGLED TRIANGLE, HAVING THE THREE SIDES GIVEN, AS $a\,b\,c$, FIG. 97.—Draw $d\,e = c$; from e with b describe an arc; and from d with a another, cutting it in f; join $d\,f$, $e\,f$. Or the angle being given and two of the sides, it may be constructed as in fig. 71.

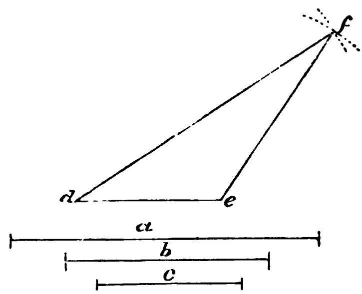


fig. 97.

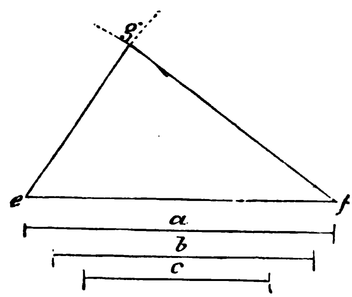


fig. 98.

TO CONSTRUCT A SCALENE TRIANGLE, HAVING THE THREE SIDES $a\,b\,c$ GIVEN.—Draw $e\,f$, fig. $98 = a$; from e, with side c, describe an arc; and from f with b cut this in g; join $e\,g$—$f\,g$.

TO CONSTRUCT A SQUARE, THE SIDE BEING GIVEN.—Let $a\,b$ be the side; draw $c\,e$ equal to this; with $a\,b$, from $c\,d$, describe arcs; from $c\,d$ draw lines, cutting these arcs perpendicular to $c\,d$; join $f\,e$, $c\,e$, $f\,d$ (fig. 99.)

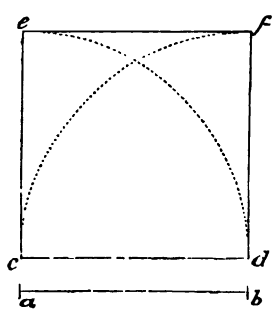


fig. 99.

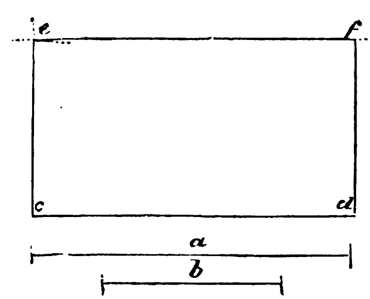


fig. 100.

TO CONSTRUCT A PARALLELOGRAM, WHEN THE LENGTH AND BREADTH ARE GIVEN.—Let a be the breadth and b, fig. 100, the length; make $c\,d = a$; from c, with radius b, describe an arc to e; raise the perpendicular $c\,e$, cutting the arc; from d, with radius b, describe an arc at f; from e, with a, cut this in f; join $e\,f$, $f\,d$.

TO CONSTRUCT A RHOMBHOID, THE SIDE AND DIAGONAL BEING GIVEN.—Let *a*, fig. 101, be the breadth; *b*, the length, and *c*, the diagonal. Draw *d e*=*b*; from *d e* with *a*, describe arcs to *g f*; from *d* with *c*, cut that in *f* at *f*; from *f* with distance *b*, cut that in *g*; join *d g*, *g f*, *f e*.

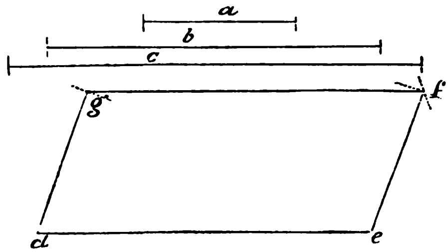


fig. 101.

TO CONSTRUCT A RHOMBUS, THE SIDE AND ANGLE BEING GIVEN.—Let *a b*, fig. 102, be the side, draw *c d* equal to it; make the angle *d c e*, equal to the angle given, and draw an indefinite line from *c* to *e*; from *c* with *a b*, cut this in *e*; do the same from *d*, and from *e* cut this in *f*; join *e d*, *f d*.

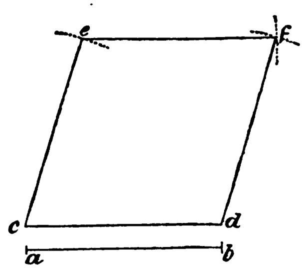


fig. 102.

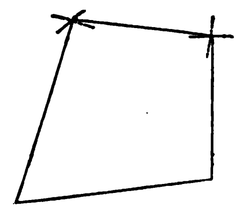


fig. 103.

The method of construction of a TRAPEZIUM may be seen by the dotted arcs in fig. 103.—It will be obvious to the pupil, that quadrilaterals, having angular sides, may be constructed by means of the protractor, scale of chords and equal parts, and the diagonal scale. Where these are used, one or more of the sides and angles must be given. Thus, to construct fig. 104, the sides and angles being all given—*c d* would first be drawn, then *c b* would be drawn at the proper angle; and *c a* cut off to the required size; *a b* would be drawn parallel to *c d*, and from *d*, *d a* at the proper angle.—The construction of figures having many sides and angles will be treated of under the head of Land Surveying, in a treatise of this series in the higher branches of Mathematics.

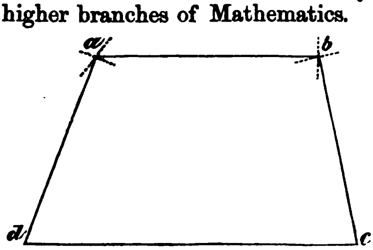


fig. 104.

TO CONSTRUCT A SQUARE ON A GIVEN LINE, *a b*, FIG. 105.—From *a* and *b*, with radius *a b*, describe arcs to *c d*; from the point *e* of intersection, with radius *e a*, describe a circle; with same radius, from *c*, *d*, cut the circle in *g* and *f*; draw *a g*; *b f* from *g*, *f*, with radius of the circle, cut these lines in *h i*, join *h i*—*a b c h* is the square required.

To construct an equilateral and equiangular pentagon on a given line, *a b*, fig. 106.—From *a* with *a b* describe the arc *b c*; draw

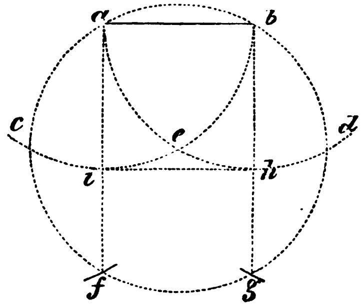


fig. 105.

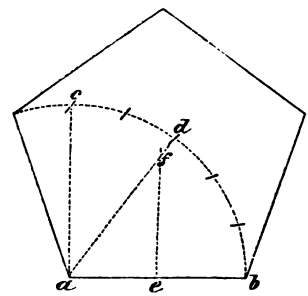


fig. 106.

the perpendicular *a c*, divide *b c* into five equal parts, draw *a d*, to the third of these from *b*; bisect *a b* in *e*; draw from this a perpendicular, cutting *a d* in *f*—from *f* with *f b* describe a circle; lay *a b* five times round this, join the points.

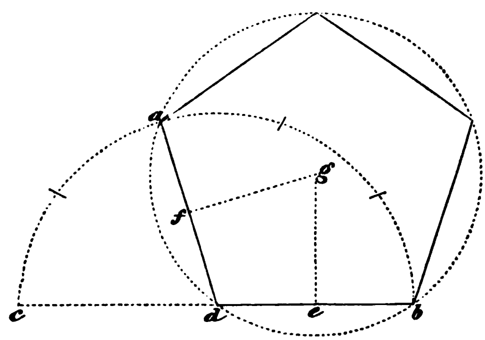


fig. 107.

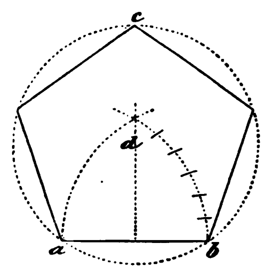


fig. 108.

Meth. 2nd.—Let *a b*, fig. 108, be the line; from *a b* describe arcs cutting each other; drop from this a perpendicular; divide the arc from *b* into six equal parts, from the point of intersection lay one of these to *d* on the perpendicular—this is the centre of a circle, which will contain *a b* five times—*d b* is the radius. *Meth. 3rd.*—Let *d b*, fig. 107, be the line; from *d* with *d b* describe a semicircle *b d c*, produce *d b* to *c*; divide this into five equal parts, through the third

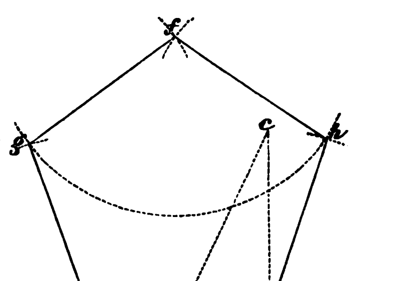


fig. 109.

of these draw *d f a*—bisect *d a, d b,* in *f* and *e*; from these draw perpendiculars cutting in *g*—it is the centre of a circle which will contain *d b* five times; the radius being = *g d.* *Meth 4th.*—Let *a b,* fig. 110,

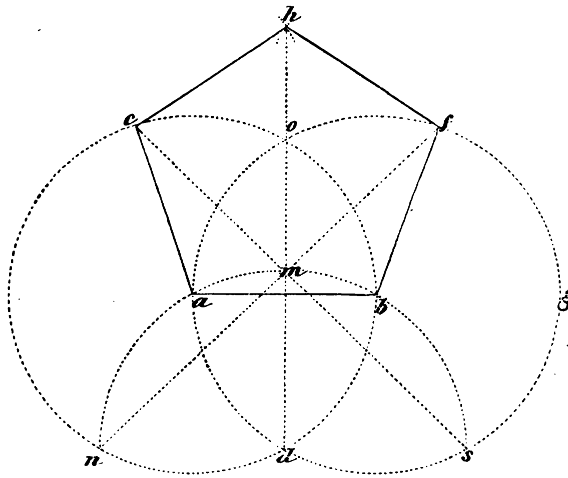


fig. 110.

be the line; from *a, b,* describe with *a b* the circles *c b d, a d f*—from the point *d,* draw through the points of intersection a line to *h*—from *d,* with radius *d ,a* describe the semicircle *n m s*; from *s* and *n,* draw through *m* to *c* and *f*; from *c* and *f,* with radius *a b,* describe arcs cutting in *h*—join *a c, c h, h f, f b.* *Meth. 5th.*—Let *a b,* fig. 109, be the line; at *b* draw *b* c perpendicular and equal to *a b*; bisect *a b* in *d,* join *c d,* from *d* with *d c* lay off to *e* on *a b* produced—from *a, b,* with disstance *a e,* describe arcs cutting in *f*; from *f* with *a b,* describe another in *g h,*; from *a b* with *a b,* cut this in *g, h*; join the points thus found.

A PENTAGON, AS FIG. 111, BEING GIVEN, IT IS REQUIRED TO DRAW ANOTHER SIMILAR TO IT.—Bisect *a b* in *c*; draw perpendicular to *a b, c d.* Draw *e f,* fig. 112=*a b*—bisect it in *g,* draw *g h,* and make it equal to

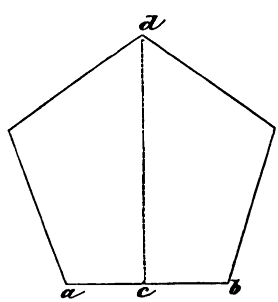


fig. 111.

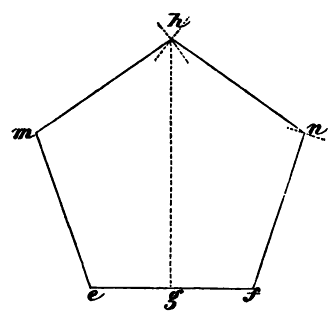


fig. 112.

c d; with radius *a b*, from *e*, *f*, *h*, describe arcs cutting in *m n*; join *e m*, *m h*, *h n*, *n f*.

An irregular pentagon, as fig. 113, being given to draw another equal and similar to it.—Draw the diagonals *a c*, *d b*. Draw any line *f g*, fig. 114=*a b*—from *f* with radius *a c*, describe an arc; from *g* with *b c* cut this in *h*, join *g h*; from *g* with *b d*, describe an arc, and from *h*

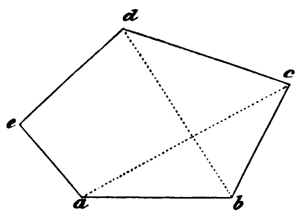


fig. 113.

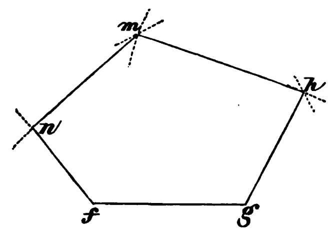


fig. 114.

with *a d*, cut this in *m*—from *m* with *d e*, describe an arc, and from *f* with *a e*, cut this in *n*—join *h m*, *m n*, *n f*.

To construct a regular hexagon.—Let *a b*, fig. 115, be the line; from *a* and *b* describe arcs cutting in *e*; from *e* with radius *e b*, describe a circle; lay *a b* six times round the circle, to *d*, *e f*, *g*—join the points thus found. *Meth. 2nd.*—Let *a b*, fig. 116, be the line; from *a* with *a b*, describe the semicircle *b e c*, on *a b* produced to *c*—divide this into six equal parts—draw *a g* to the fourth of these; bisect *a b*, *g a*, in *d* and *o*; draw perpendiculars from these cutting in *e*; from *e*, with radius *e a*, describe a circle—with *a b* from *g*, cut this in *h*, from *h* cut it in *m*, and from *m* in *f*—join these points.—*Meth. 3rd.*—Let *a b*, fig. 117, be the side; bisect it in *c*, draw *c e* perpendicular to *a b*; from *a* describe an arc with *a b*, cutting *c e* in *d*; through *d* draw *f d g* parallel to *a b*; from *d* lay off to *f g* equal to

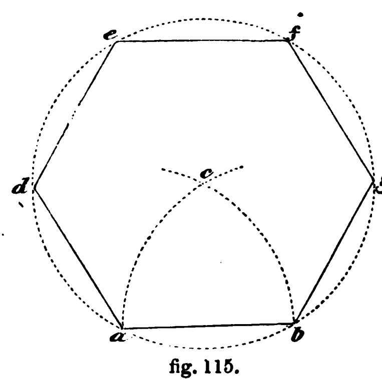


fig. 115.

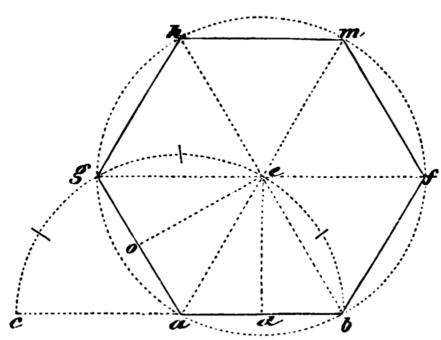


fig. 116.

d b—make *d e*=*d c*, through *e*, draw *m n*, parallel to *a b*; from *a b* draw through *d*, cutting *e m n* in *m n*; join the points in *m f n g*, &c. *Meth. 4th.*—Let *a b*, fig. 118, be the side; bisect it in *c*, draw *c d*, and from

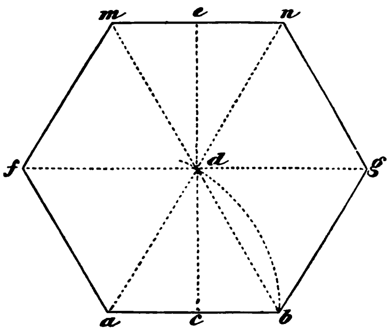


fig. 117.

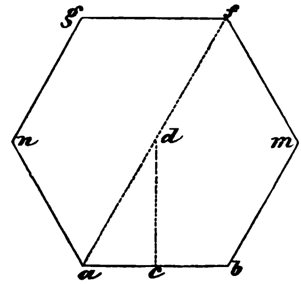


fig. 118.

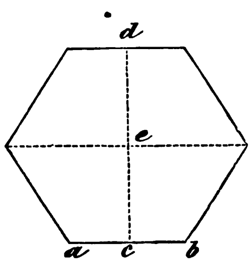


fig. 119.

a with *a b*, cut it in *d*—from *a* draw through *d* to *f*—from *d* with *d a* cut this in *f*; from *f* make *f g* parallel and equal to *a b*; from *f*, *g*, with *a b*, describe arcs in *m n*; from *a b* cut these, join the points.

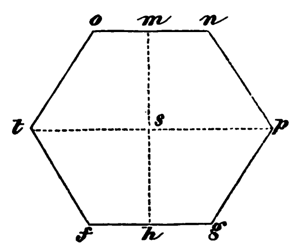


fig. 120.

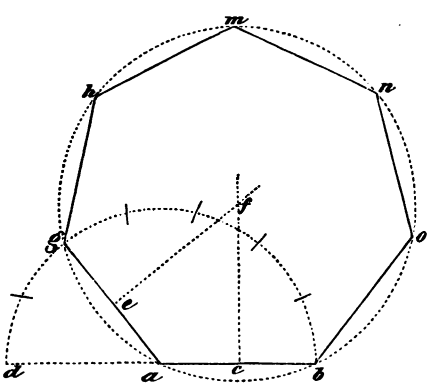


fig. 121.

A HEXAGON, AS FIG. 119, BEING GIVEN, TO DRAW ANOTHER EQUAL AND SIMILAR TO IT.—Bisect *a b*, fig. 119, in *c*, draw *c d*, and join the opposite angles by a line through *e*. Draw *f g* (fig. 120)=*a b*; bisect it in *h*, draw *h m*=*c d*, bisect this in *s*, draw *t s p* parallel to *f h g*, from *m* make *o*, *n*=*f g*; from *o*, *n* with *f g*, cut *t s p* in *t* and *p*, join the points. An irregular hexagon, as that in fig. 33, may be drawn in the same way as figs. 113 and 114.

A SIDE BEING GIVEN TO CONSTRUCT A HEPTAGON.—Let *a b*,

fig. 121, be the side; with this radius from *a*, describe a semicircle *b g d* on *a b*, produced to *d*; divide it into seven equal parts; through the fifth of these draw *a g*; bisect *a b*, *a g* in *c e*; erect perpendiculars from these points, cutting in *f*; from *f*, with *f a*, describe a circle; lay *a b* from *g* to *h*, *m*, and *n o*—join the points. *Meth. 2nd.*—Let *a b*, fig. 122, be the side; from *b*, with *a b*, describe an arc *a e*; bisect *a b* in *c*, draw a perpendicular, as *e d*; divide *a e* into seven parts, lay one of these from *e* to *d*—*d* is the centre of a circle (the radius of which is *d a*), which will contain *a b* seven times.

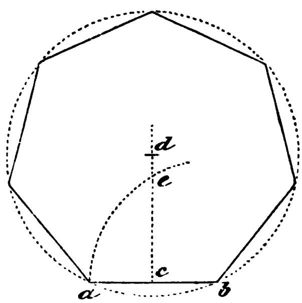


fig. 122.

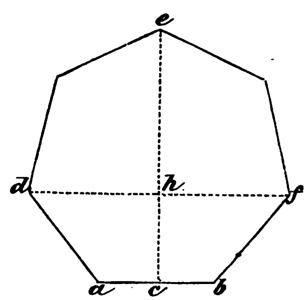


fig. 123.

A HEPTAGON, AS FIG. 123, BEING GIVEN, TO CONSTRUCT AN EQUAL AND SIMILAR ONE, AS FIG. 124.—Bisect *a b*, fig. 123, on *c* draw *c e*, join *d f*, make *a b*, fig. 124,$=$*a b*, fig. 123; bisect it in *c*, join *c f*; make *c m*$=$ *c h*, and *m n*$=$*h f*, join *n n*; make *c f*$=$*c e*; with *a b*, from *a*, *b*, *n n*, *f*, describe arcs cutting each other—join the points thus found.

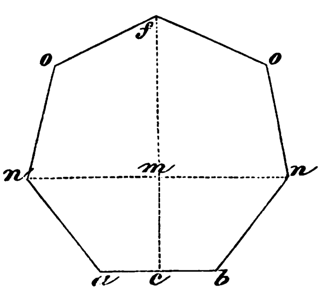


fig. 124.

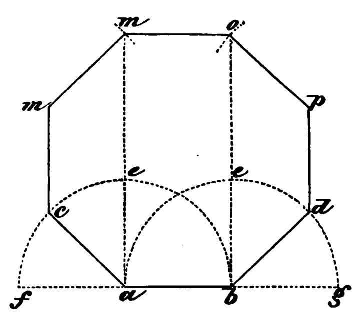


fig. 125.

A SIDE BEING GIVEN, AS *a b*, FIG. 125, TO CONSTRUCT A REGULAR OCTAGON THEREON.—With radius *a b* from *a b*, describe semicircles on *a b*, produced to *f g*; divide these into four equal parts each; through the third of these draw *a c*, *b d*; from *a b*, through *e e*, the second points, draw to *m o*; parallel to these, from *c d*, draw to *m p*$=$*a b*; from *m p*, with *a b*, cut *a m*, *o b* in *n o*—join the points, *Meth. 2nd.*—Produce

the side *a b*, fig. 129, to *d c*; from *a b*, erect perpendiculars to *m n*; divide *a b* into four equal parts, lay three of these to *c d*; from these draw lines parallel to *a m*; from *a b*. with *a b*, cut these in *h*, *g*; make *h o*, *g o*=*a b*; and from these, with *a b*, cut *a m*, *b m* in *m n*—join the points. *Meth. 3rd.*—A square, fig. 126, can be converted into an octagon, as follows:—From *a b*, *c d*, draw diagonals; and from these points, with *b e*, where the diagonals intersect, describe arcs cutting the sides in certain points—join the points.

An octagon, as fig. 127, being given, to construct an equal and similar one.—Bisect *a b* in *c*, erect *c d*; join *a e*, *b e*; through *f* draw *f g* parallel to *a b*; make *a b*, fig. 128=*a b*, fig. 127; bisect it in *c*, draw *c d*, and *a o*, *b o*, and through *e*, *g e f*; with *f g*, fig. 127, make *e g*, *e f*, equal; through these, draw lines parallel to *c d*; with *a e*, fig. 127, from *a b*, cut *a o*, *b o* in *o o*; and from *a b*, *o o*, describe other arcs, cutting the lines *g f*—join the points.

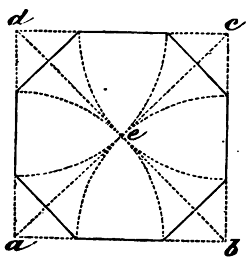


fig. 126.

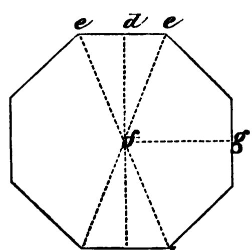


fig. 127.

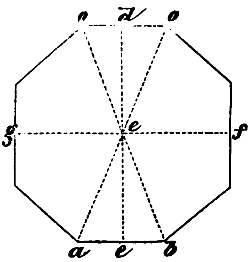


fig. 128.

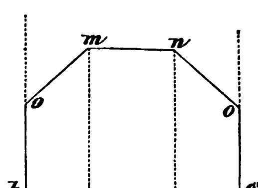


fig. 129.

To construct on a given line any polygon, having from six to twelve or twenty-four sides.—Let *a b*, fig. 130, be the line; from *b*, with *a b*, describe an arc *a e*; bisect *a b* in *c*, and erect an indefinite perpendicular, as *c e*; divide the arc *a e* into six equal parts; from *e* transfer these to the line *e c*.

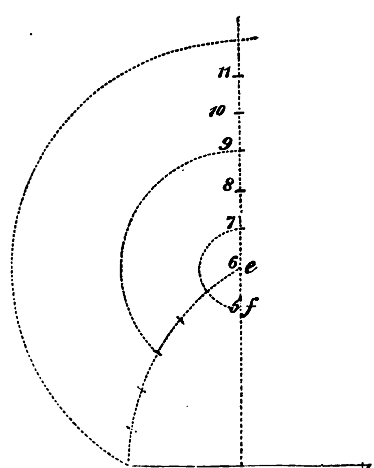


fig. 130.

TO CONSTRUCT A HEXAGON.—On *a b*, from *e*, with radius *e a*, describe a circle. This will contain *a b* six times.—For a heptagon, octagon, nonagon (nine-sided figure), decagon (ten-sided), undecagon (eleven-sided). dodecagon (twelve-sided), the centre of the circle is respectively at the points 7, 8, 9, 10, 11, and 12. A polygon, having from twelve to twenty-four sides, can also be constructed by the same means, by dividing the arc into twelve equal parts, and proceed as above. In fig. 130, *f* is the centre of a circle, containing *a b* five times. The sides of a regular pentagon, hexagon, &c., can be found by means of the protractor. The rule is simple. Divide 360°, the number of degrees on the circumference of a circle by the number of the sides of the desired polygon. This will give the angle at the centre of the circle, in which, or about which, the figure is to be inscribed or described. If the figure is to be constructed on a given line, the angle found as above, is to be substracted from 180°—the angle thus found is that to be used. Thus, suppose a pentagon is to be inscribed in the circle, fig. 108, 360° divided by 5 gives 72°. From *d*, the centre of the circle, draw a line, touching the circumference in *a*; lay the edge of the protractor to coincide with the line *d a*, and the central part with the centre *d*; make a line, drawn from *d* to *b*=72°; join *a b*—it is the side of the pentagon required. Suppose the pentagon is to be erected on the line *e f*, fig. 112. Subtract 72° from 180°, this leaves 108°; lay the protractor to coincide with *e f*, and the central point with point *e*; make a line *e m*=*e f*, and at an angle of 108°, with *e f*; at *m* make *m h*=*e f*; and at an angle of 108°, with *e m*, and so on. All the other figures can be constructed by the rule given above.

We shall now proceed to problems, showing the methods of inscribing and describing figures, within and without others.

TO INSCRIBE A CIRCLE WITHIN A TRIANGLE.—(Fig. 131.)—Bisect the angles *a b c*, *a c b*, by lines cutting in *d*; from *d* draw to *e* perpendicular to *b c*; from *d*, with *d e*, describe the circle.

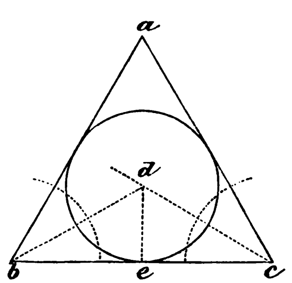


fig. 131.

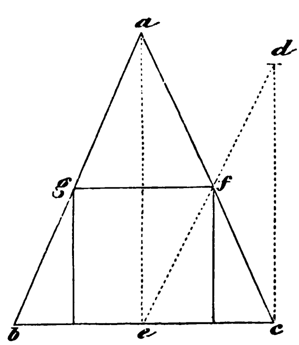


fig. 132.

TO INSCRIBE A SQUARE IN A TRIANGLE.—(Fig. 132.)—From *c* draw *c d*, perpendicular and equal, to *c b*; bisect *b c* in *e*, join *e d*; from where this cuts *a c*, as *f*, draw *f g* parallel to *b c*—*f g* is the side of the square.

To inscribe a pentagon in an equilateral triangle.—(Fig. 133.)—Perpendicular to *b c* draw an indefinite line *b d*; from *b*, with *b c*, describe the arc *b c e*; divide *d c* into five equal parts; lay one from *d* to *e*; join *b e*; bisect it in *f*; from *b*, with *b f*, describe the arc *f g*; join *f g*, produce it to *h*; make *b m*=*c h*; join *e a*, cutting *m g* in *n*; from *g*, with *g n*, describe the arc *n n*, from these points, with same radius; cut *a b*, *a c* in *o o*—join the points.—*Meth. 2nd.*—Let *a b c*, fig. 134, be the triangle; bisect *b c* in *d*, draw *d a*; divide *d b* into six equal parts; from *c* lay off one of these to *e*; and from *c* and *b* three of them to *g h*; join *d g*, *d h*; join *a e*, cutting *d g* in *m*; from *d* with *d m*, describe an arc, cutting *d h* in *n*; from *m n*, with same radius, describe arcs, cutting *b a*, *c a*, in *o* and *s*, join *o n*, *s m*.

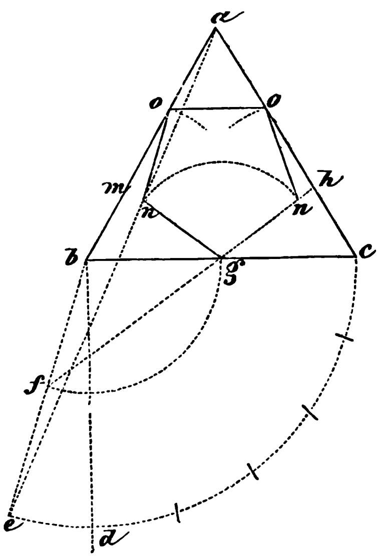


fig. 133.

To inscribe a square in a given square.—(Fig. 135.)—Bisect *c d* in *e*; from *d* and *a*, with *d e*, describe arcs *e f g* h—join the points thus obtained.

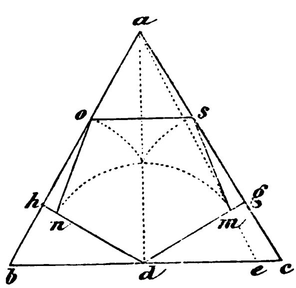


fig. 134.

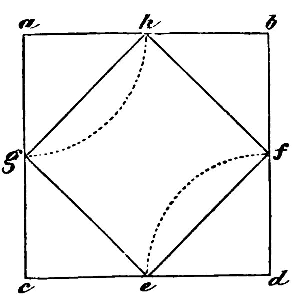


fig. 135.

To inscribe an equilateral triangle in a given square.—(Fig. 136.)—Draw the diagonals *a d*, *b c*, cutting in *e*; from *d*, with *d e*, describe the arc *f e g*—join *f g*, *a f*, *a g*.

To inscribe an isosceles triangle of greatest dimensions in a given square.—(Fig. 137.)—Bisect *a b* in *f*—join *c f*, *d f*.

To inscribe a circle within a square.—(Fig. 138.)—Draw diagonals, cutting in *e*; from *e* parallel to *c d* draw *e f*—from *e*, with *e f*, describe the circle.

To INSCRIBE A HEXAGON IN A GIVEN SQUARE.—(Fig. 139.)—Bisect the side *a c* into two parts in the point *b*; divide *a b* into seven equal parts; lay three of these from *a* to *d*; join *b d*; and with this distance lay off to *e* in the side *a d e*; from *e* to *f*, *g* and *h*, join the points.

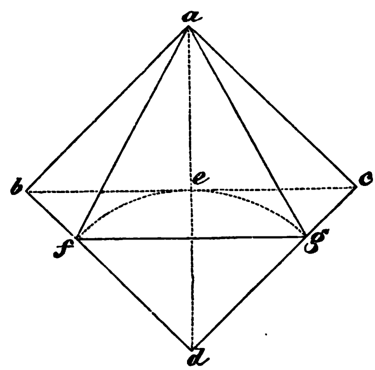


fig. 136.

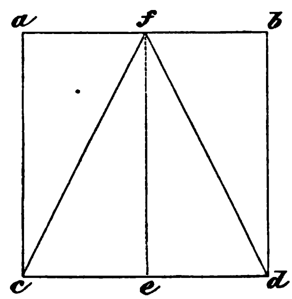


fig. 137.

To INSCRIBE AN OCTAGON IN A GIVEN SQUARE.—(Fig. 140.)—Draw the diagonals, cutting in *e*; from the corners, with *b e*, describe arcs—join the points thus found.

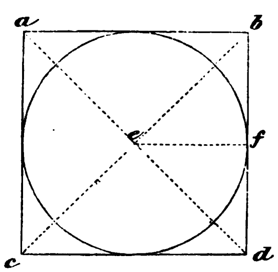


fig. 138.

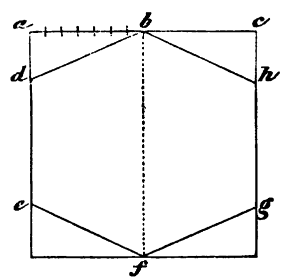


fig. 139.

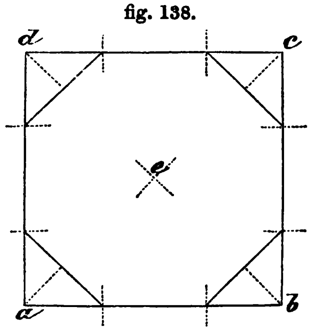


fig. 140.

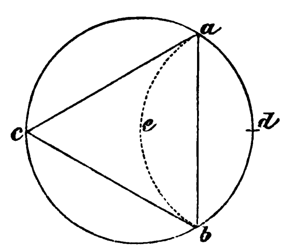


fig. 141.

To INSCRIBE AN EQUILATERAL TRIANGLE IN A CIRCLE.—(Fig. 141.)—From any point *d* in the circumference, with *d, e* (the centre), describe an arc, cutting the circle in *a b*; from *a b*, with *a b*, describe an arc cutting in *c*; join *c a, c b, a b*.

To INSCRIBE A SQUARE IN A CIRCLE. — (Fig. 142.) Draw diameters at right angles to one another, cutting the circumference in four parts; join these. *Meth. 2nd.*—Draw the diameters *a b c d*; divide any two of these quadrants thus formed, in *f* and *g*; from these draw *e g, f h* parallel to *d e*—join *e f, g h* (fig. 143).

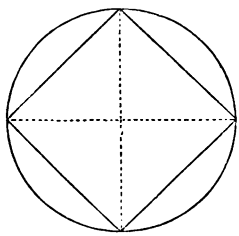


fig. 142.

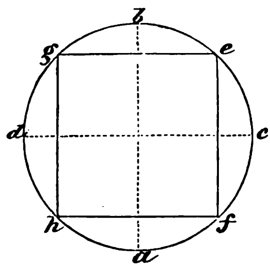


fig. 143.

IN A GIVEN CIRCLE TO INSCRIBE A RECTANGLE OF GREATEST DIMENSIONS.—(Fig. 144.)—Divide the diameter *a b* into four equal parts; through the first and third draw lines *d f, c e* at right angles to *a b*—join *c d, e f*.—*Meth. 2nd.*—(Fig. 145.)—Draw any two diameters—join the points where they cut the circumference.

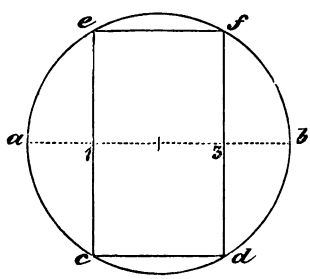


fig. 144.

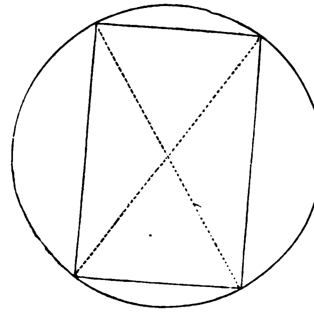


fig. 145.

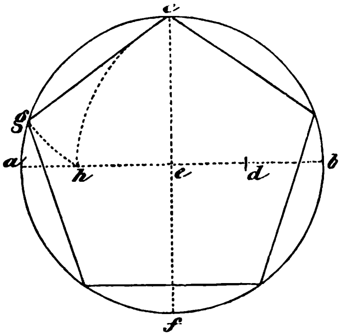


fig. 146.

To INSCRIBE A PENTAGON IN A GIVEN CIRCLE.—Draw diameters intersecting in *e* (fig. 146); bisect *e b* in *d*; from *d*, with *d c*, describe the arc *c h*; from *c*, with *c h*, describe an arc cutting the circle in *g*—join *c g*, it is the side of the pentagon required. *Meth. 2nd.*—(Fig. 147.)—Draw the diameter *a b*; divide it into five equal parts; from *a b*, with *a b*, describe arcs cutting in *d*; through the second of the points from *a*, draw from *d* to *c*—join *a c*, it is the side required.

To INSCRIBE A HEXAGON IN A GIVEN CIRCLE.—(Fig. 148.)—The method last

described is applicable to this problem. The diameter being divided into six parts, *a c* is the side required. *Meth. 2nd.*—(Fig. 149.)—Draw the diameter *a b* from *a* with *a c* (the centre of the circle); describe an arc cutting the circle in *d e*—join *a d*, it is the side required.

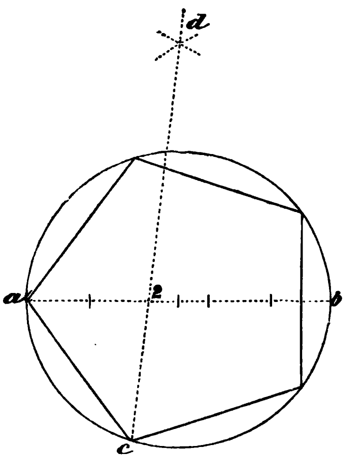


fig. 147.

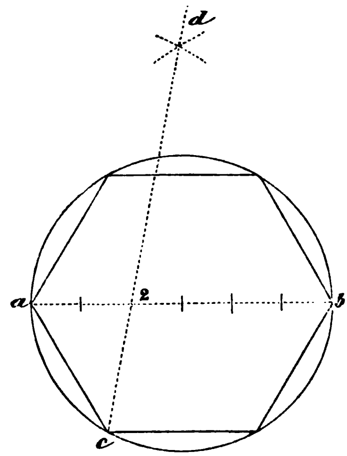


fig. 148.

TO INSCRIBE AN OCTAGON IN A GIVEN CIRCLE.—(Fig. 150.)—Draw diameters intersecting in *e*; bisect each of the quadrants thus obtained; join the points.

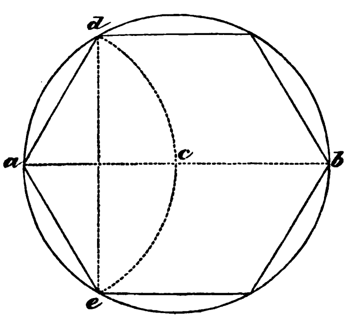


fig. 149.

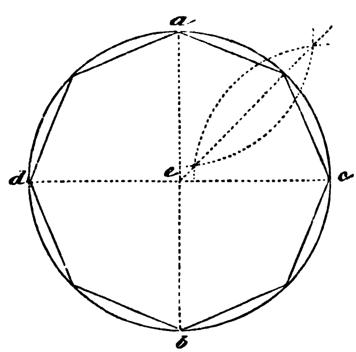


fig. 150.

TO INSCRIBE A DODECAGON, OR TWELVE-SIDED FIGURE, IN A CIRCLE.—(Fig. 151.)—Draw diameters intersecting in *e*; with *a e*, from *a b c d*, cut each quadrant in two points; join these.

TO INSCRIBE AN EQUILATERAL TRIANGLE IN A GIVEN PENTAGON.—(Fig. 152.)—Join the opposite angles by lines *d b*, *e c*, cutting in *g*; join *a f* through *g*—lay off *f g* from *g* to *h*; from *h*, with *h a*, describe a circle

about the pentagon; from *a*, with *a h*, describe the arc *m h n*; bisect *m h*, *h n*, in *o o*; through these from *a* draw lines, cutting *e b*, *d c*, in *s* and *t*; join *s t*.

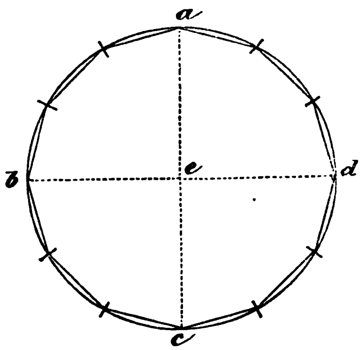


fig. 151.

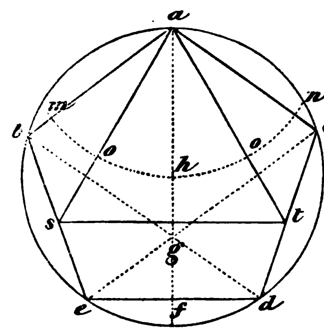


fig. 152.

To INSCRIBE A SQUARE IN A PENTAGON.—(Fig. 153.)—Join the angles *c*, *b* from *c* perpendicular, and equal to *c b*, draw *c d*; (from want of space this line is not given in full), join *a* and the extremity of *d*; from the point *e*, where it cuts *c e*, draw *e f* parallel to *b c*; *e f* is the side required.

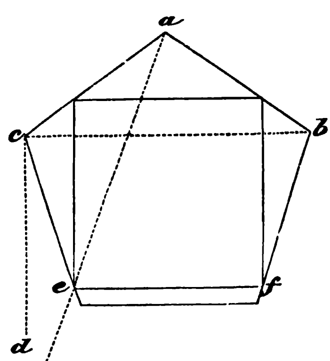


fig. 153.

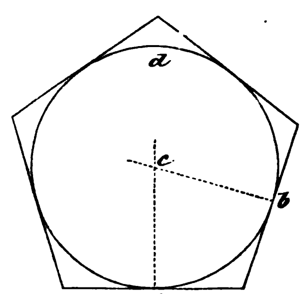


fig. 154.

To INSCRIBE A CIRCLE IN A PENTAGON.—(Fig. 154.)—Bisect any two of the sides, in *a* and *b*; draw perpendiculars from these intersecting in *c*, with *c a* from *c* describe *a b d*.

To INSCRIBE A HEXAGON IN A GIVEN PENTAGON.—(Fig. 154.)—Inscribe a circle as above, and thereafter a hexagon in the circle.

To INSCRIBE AN EQUILATERAL TRIANGLE IN A GIVEN HEXAGON.—(Fig. 155.)—Bisect any two of the sides, as *a b*, *c d*, in *e f*; join *e f*, from *e f*, with *e f*; describe arcs, cutting in *g*; join the points.

To DESCRIBE A CIRCLE ABOUT A TRIANGLE.—(Fig. 156.)—Bisect *a b*, *a c*, by lines cutting in *d*; from *d*, with *d b*, describe the circle.

To DESCRIBE A CIRCLE ABOUT A SQUARE.—(*g e h f*, Fig. 143.)—Draw the diagonals; the part where they intersect is the centre of the circle.

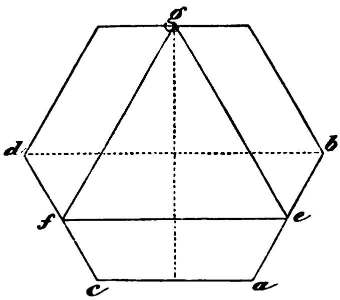


fig. 155.

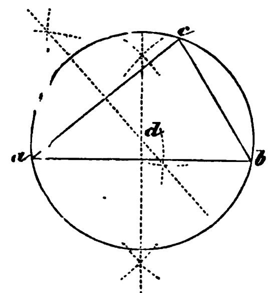


fig. 156.

To DESCRIBE A TRIANGLE ABOUT A CIRCLE.—(Fig. 157.)—Draw the diameter *a b*; from centre *c* draw *c d* perpendicular to *a b*; draw any line *e f*; from centre *d* lay off the length of base *e f*; from *e f*, touching the circle in *h g*, draw lines to *m*.

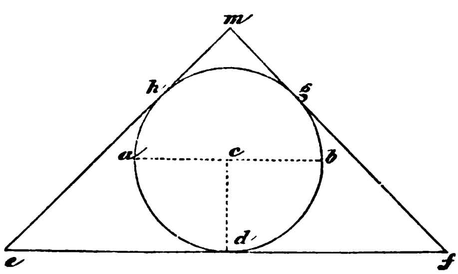


fig. 157.

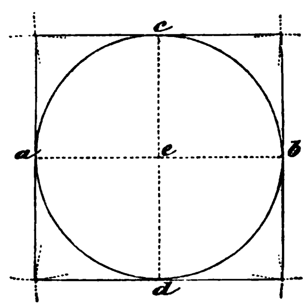


fig. 158.

To DESCRIBE A SQUARE ABOUT A CIRCLE.—(Fig. 158.—Draw diameters, cutting in *e*; with *a e*, from *a b c d*, describe arcs cutting each other; join the points.

To DESCRIBE A SQUARE ABOUT

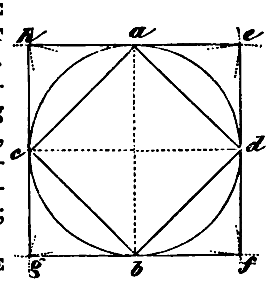


fig. 159.

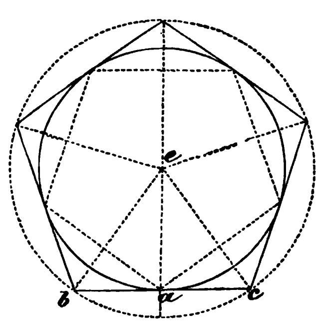


fig. 160.

A GIVEN CIRCLE.—(Fig. 159.)—Draw two diameters intersecting at *c*, with the radius of the circle, from the points of the diameters, *a b*, *d c*, describe arcs, cutting in *f g h e*—join these points.

TO DESCRIBE A PENTAGON ABOUT A CIRCLE.—(Fig. 160.)—Inscribe in the circle a pentagon, by any of the rules already given; bisect the sides of this, and from the points draw lines, cutting in *e;* from *e* draw to *b*; and through *a* draw a tangent *b a c* to the circle; from *e*, with *e b*, describe a circle; points are obtained where the radial lines from *e* cut this; join the points.

TO DESCRIBE A PENTAGON ABOUT AN EQUILATERAL TRIANGLE.—(Fig. 161.)—From *a* and *b*, with any radius, describe arcs *f g*, *d k*; draw *a m* perpendicular to *b c*; divide *m o* into five parts; from *o*, with four of these describe the arc *f t*; with *f t* set off from *k* to *d*; join *a f d;* make $r\,g = o\,f$; through *g* draw $a\,g\,n = c\,f\,d$; from *n d*, with *a d*, measure to *s s;* join *d b s*, *n c s*, and *s s*.

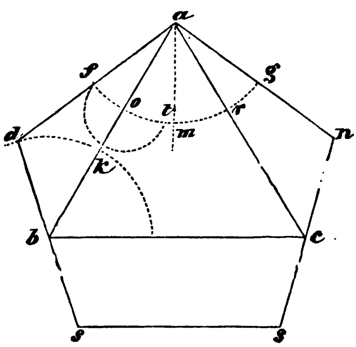


fig. 161.

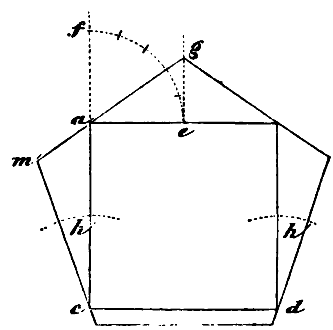


fig. 162.

TO DESCRIBE A PENTAGON ABOUT A SQUARE.—(Fig. 162.)—Produce *c a* to *f;* bisect *a b* in *e*; draw the perpendicular *e g*, from *a c d*, with *a e*, draw the arc *a e f*, *h h;* divide *e f* into 5=parts; through the second

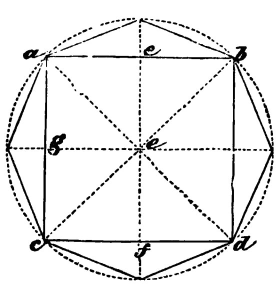


fig 163.

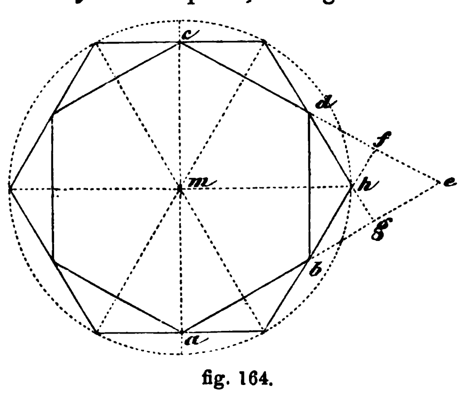


fig. 164.

of these draw *a g*; with one of them lay off from the sides *c a*, *b d*, in the arcs *h h*; from *c* draw through *h* to *m*; produce *g a* to meet this in *m*; two of the pentagonal sides are found.

To describe an octagon about a square.—(Fig. 163.)—Draw diagonals, cutting in *e*; from *e*, with *e b*, describe a circle; bisect *c d*, *c a*, in *f* and *g*, from these draw lines through, meeting the circle; join the points.

To describe a hexagon about a hexagon.—(Fig. 164.)—Produce *a b*, *c d*, to *e*; bisect *b e*, *d e*, in *f g*; draw from *b* and *d* through these, cutting in *h*; from *m*, the centre of the given hexagon, with *a h*, describe a circle; bisect all the sides of the hexagon, as *a b*, *c d*; through the centre *m* from these draw lines, touching the circle; join the points.

To describe a square about an equilateral triangle.—(Fig. 165. —Bisect *b c* in *d*; draw *d a*; produce *b c*; make *d e*, *d e*=*d a*; join *e a*; from *d*, with *d c*, describe *c f b*—from *f*, through *b c*, draw to *h g*.

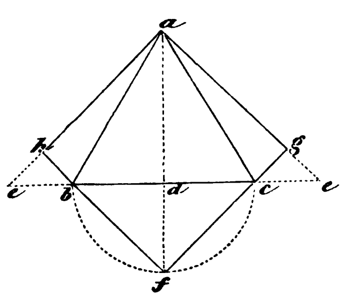


fig. 165.

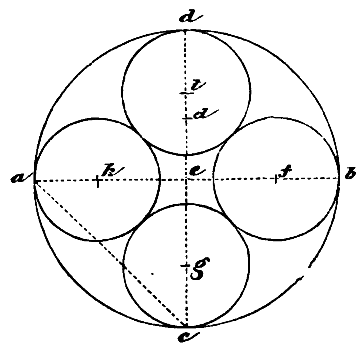


fig. 166.

To inscribe four circles within a circle.—(Fig. 166.)—Draw diagonals, cutting in *e*; join *a c*; from *c*, with *a c*, lay off on *c d* to *d*; with *d c*, from *a b c d*, lay off in the diameters to *g h t f*; with radius *f b* describe from these points the four circles.

To inscribe three circles within an eqilateral triangle.—(Fig. 167.)—Bisect the sides in *d e f*, and from these draw to the opposite

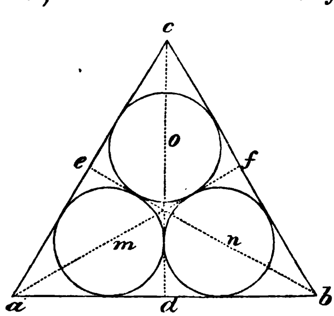


fig. 167.

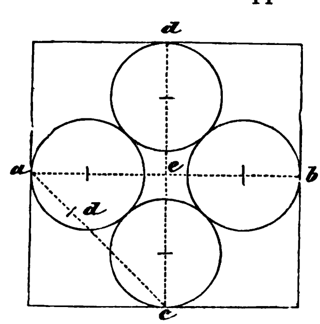


fig. 168.

angles; with *a d*, from *e f d*, lay off to *m n o*; describe from these the three circles. NOTE.—By joining the points *m n o* by lines, a triangle may be inscribed within the other.

TO INSCRIBE FOUR CIRCLES WITHIN A SQUARE.——(Fig, 168.)—Bisect the sides, and draw lines from the points, cutting in *e*; join *a c*; from *c*, with *c e*, cut *a c* in *d*; with *d a*, from *a b c d*, lay off in the diameters; these are the centres of the circles of which *a d*= radius.

A TRIANGLE BEING GIVEN, TO CONSTRUCT A PARALLELOGRAM EQUAL TO IT.—(Fig. 169.)—From the apex *a* draw *a e* parallel to *b c*; from *a* draw a perpendicular to *d*; from *c* draw to *e* parallel to *a d*. *Meth. 2nd*, From *a*, fig. 170, draw *a e* parallel to *b d*; bisect *b d* in *c*; from *c* draw *c f*, the angle *d c f*=*d b a*; from *d* draw *d e* parallel to *c f*. This is the figure known as a rhomboid.

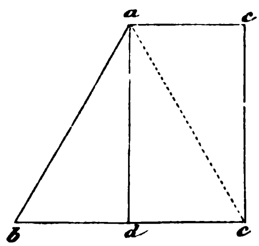


fig. 169.

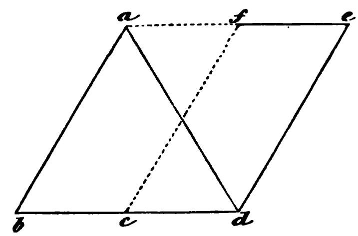


fig. 170.

TO CONSTRUCT A PARALLELOGRAM EQUAL TO A TRIANGLE.—(Fig. 171. —Draw the diagonal *a d*, produce *c d* to *e*; from *b* draw *b e* parallel to *a d*; join *b c*, *e c b*=*a b c d*.

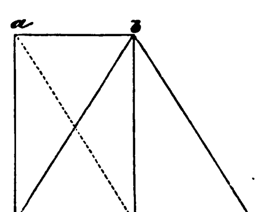


fig. 171.

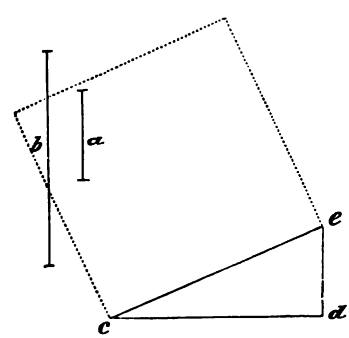


fig. 172.

TO CONSTRUCT A SQUARE EQUAL TO TWO SQUARES, OF WHICH THE SIDES, *a b*, ARE GIVEN.—(Fig. 172.)—Draw *c d*=*b*, and *d e* at right angles to *c d*=*a*—join *c e*, it is the side of the square required.

To construct a square equal to a given rectangle.—(Fig. 173.)—Produce the base $b\,c$ to e; from c with $c\,d$ describe the arc $e\,d$, bisect $b\,e$ in f, from f with $f\,e$ describe the semicircle $e\,h\,b$; produce $c\,d$ to h; $c\,h$ is the side of the square—$n\,m\,h\,c = a\,b\,c\,d$.

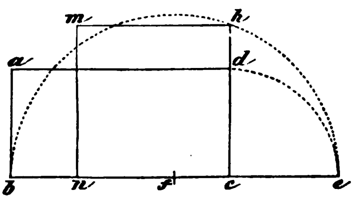


fig. 173.

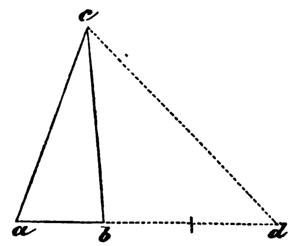


fig. 174.

To construct a triangle to contain three times a given triangle.—Let $a\,b\,c$, fig. 174, be the triangle.—Produce $a\,b$ to d, lay from b three times $a\,b$ to d, join $c\,d$.

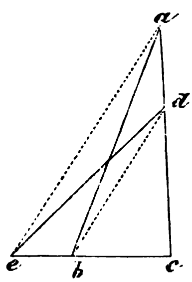


fig. 175.

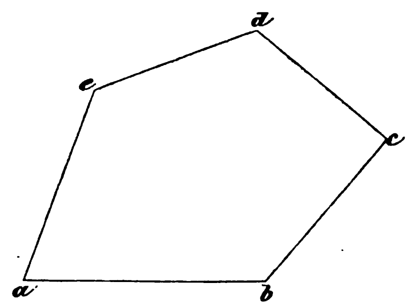


fig. 176.

To construct a triangle equal to a given angle $a\,b\,c$ (Fig. 175), but of less height.—Let d be the point to form the apex of the required angle; produce $c\,b$ to e, join $d\,b$; from a draw $a\,e$ parallel to $d\,b$; join $d\,e$, $d\,e\,c = a\,b\,c$.

To draw any irregular polygon by means of the scales of equal parts, diagonal scales and protector, the sides and angles being given.—Draw $a\,b$, fig. 176 = the length given, say 250 feet, taken from the diagonal scale; make $b\,c = 150$, and at an angle of 50° to $a\,b$; at an angle of 90° draw $c\,d = 175$; make $d\,e = 180$, and the angle 120°; join $e\,a$, it will be = 217, and the angle 129° 30'.

To reduce a polygon to a quadrilateral.—Produce $a\,e$, fig. 177, indefinitely; join $e\,c$; from d draw $d\,f$ parallel to $c\,e$; join $c\,f$; $f\,a\,b\,c = e\,a\,b\,c\,d$.

A quadrilateral being given to reduce it to a triangle.—(Fig. 178.)—Produce $a\,b$ indefinitely, join $d\,b$; from c draw $c\,e$ parallel to $d\,b$; join $d\,e$.

An irregular figure being given to construct another similar to it, but reduced or enlarged.—Let the figure be reduced one-half; draw the diagonals, joining the opposite angles; bisect *a b*, fig. 179, in *g*; from *g* draw a line parallel to *b c*, cutting *a c* in *h*, *g h* is=*b c*; from *h* draw to *m*, parallel to *d c*; proceed till the figure is complete. If the figure had to be enlarged, *a*, *b*, and all the diagonals should be produced, and lines drawn parallel to those given.

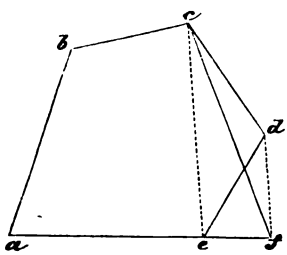


fig. 177.

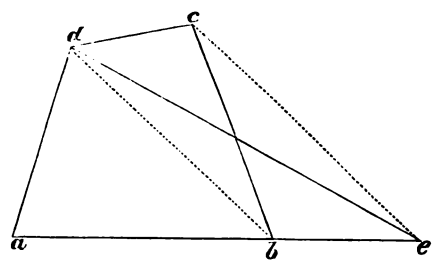


fig. 178.

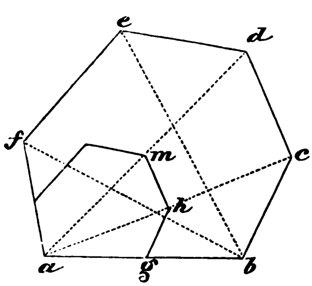


fig. 179.

An irregular figure being given to construct another equal and similar.—(Fig. 180.)—From *b* draw *b o* perpendicular to *a b*; and draw from the angles of the figure, lines parallel to *a b*; draw *m n*, fig. 181=*a b*, draw *n o* perpendicular to *m n*; take from *b* the height in *b o* where the parallel lines cut it, and lay them off respectively to *n o* from *n*—through the points thus obtained draw lines parallel to *m n*—from *n* with *b c* cut the first parallel in 1—from 1, with *c d*, cut the third in 2; from 2, with *d e*, cut the fourth at *o*—from *o* with *e f* cut the fifth in *s*; from *s*, with *f g*, cut the second in *v*; from *m*, with *a g*, cut this in *v*,

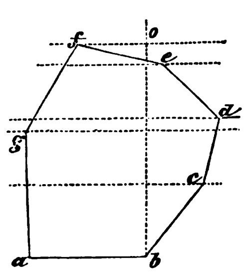


fig. 180.

An irregular figure being given to construct another equal and similar, but in a reversed position.—(Fig. 182.)—The method is similar to the above, the letters on the diagram, and that in fig. 183, will render much description unnecessary. From any part in *b c* erect perpendiculars, make their position the same in both lines; with *c d* from *c*, fig. 183, draw to the first parallel, by proceeding thus the figure will be constructed as desired. Figures having irregular sides can be copied, reduced, enlarged, or made equal, by means of squares, as in figs. 184 to 189. Suppose fig. 184 to be copied double the size—Draw any number of horizontal and parallel lines across the face of the

diagram, at equal distances from each other; at the same distance draw other lines perpendicular to the others. There will thus be described a series of squares, the boundary lines of which will enclose the figure. By drawing the same number of lines perpendicular to one another, but at double the distance of those in fig. 184, a series of similar but enlarged squares will be obtained, as in fig. 185. The points at which the terminations of the figure in fig. 184 touch the lines, or are placed in the square, must be ascertained and transferred to corresponding points and situations in fig. 185. Fig. 189 is a similar one to fig. 188; two times larger, but as will be observed, it is reversed. The angle at the top, in fig. 188, being in the lowest position in fig. 189. Fig. 187 is a similar figure to fig. 186, but enlarged as $1\frac{1}{2}$ to 1; the angle at the right hand in fig. 186 is placed at the left hand in fig. 187. These examples, aided by the annexed numbers will show the pupil the method of using a system of squares for reducing, enlarging, or drawing equal and similar figures, in transposed positions, or otherwise. We shall now proceed to the construction of the curves, known as the "conic sections,"

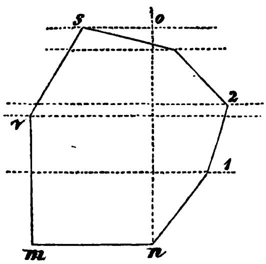


fig. 181.

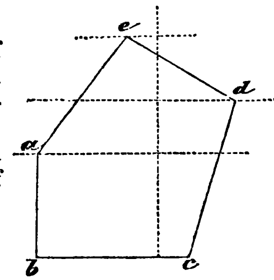


fig. 182.

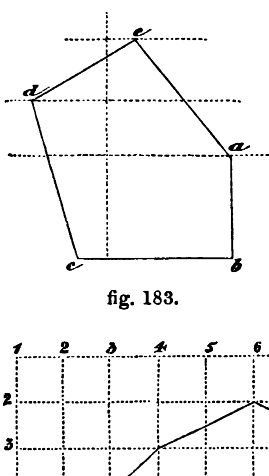


fig. 183.

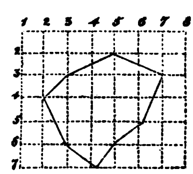


fig. 184.

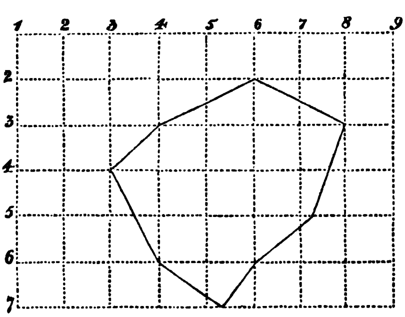


fig. 185

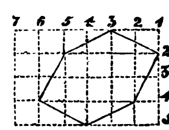


fig. 186.

TO DESCRIBE AN ELLIPSE IN A GIVEN LINE.—(Fig. 190.)—Divide *a b* into three equal parts; from *c d*, with *c a*, describe two circles cutting in *e*; through the centre and the points of intersection draw lines as *c f*, *d e*; from the point of intersection take to *f* in the compasses; from the

points, as *e*, describe parts of circles joining the small ones previously described, as *f f*. *Meth. 2nd* (Fig. 191).—Divide the line *a b* into four equal parts; from *c d*, the first and third, describe with radius *a c* two circles; from *c d*, with *c d*, describe arcs cutting in *e*, on both sides of *a b*; from *e* draw through *d* to *g*, with *e g*; from *e* describe parts of circles joining those previously drawn. *Meth. 3rd—The diameters being given.*—(Fig. 192.)—Let *a′ b′* be the diameters; draw *a b*=*a′*; bisect it in *e*, draw *e a*, *d c*=half of *b′*, *d c* will therefore equal *b′*. Take *c d*, and from *d* lay it on *a b* to *f*; divide *f b* into three equal parts; with two of these from *e* lay on *a b* to *g*; make *e h*=*e g*; from *h g*, with *h g*, describe arcs in *m n*; from *h g*, with *a h*, describe parts of circles *a b*;

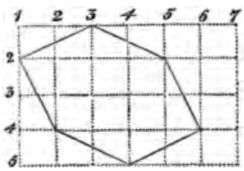


fig. 187.

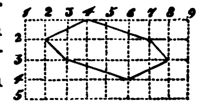


fig. 188.

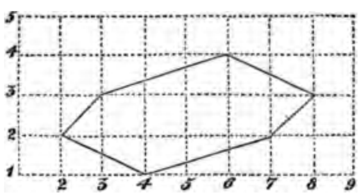


fig. 189.

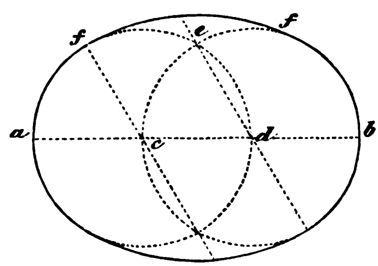


fig. 190,

from *m* draw through *g*, touching the circle described from *g*; from *m n*, describe arcs as in preceding problems. *Meth. 4th.*—Let *a b*, *c d*, fig. 193, be the diameters. With *c e* from *b* lay off to *f*; divide *f e* into three equal parts; from *f*, with one of these, dessribe a semicircle to *h*; make *e g*=*e h*; proceed as in last problem. *Meth. 5th.*—An ellipse may be described without compasses, on a large scale, as follows:—Let *a b*; fig. 194, be the length of proposed ellipse, and *c d* half its breadth; bisect *a b* in *c*, draw *c d* perpendicular to it; with *a c*, from *d*, cut *a b* in *e* and *f*, in *d e f* fix pins; fasten a cord round *e*, carry it round *d*, and fasten it firmly to *f*; take out the pin *d*, and substitute for it a pencil or tracer; keep the cord tight, and from *d*, towards *a*, move the tracer, and from *d* to *b*; half of the ellipse will be described; move the cord to the other side of the pins for the remaining half.

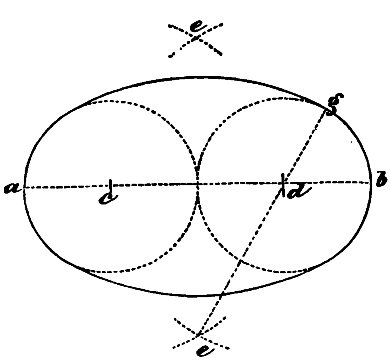


fig. 191.

To draw an ellipse round two squares.—(Fig. 195.)—Let *a b c d*, *e f d c* be the squares; draw the diagonals as in the diagram; from *g* and *h*, *c* and *d*, describe the parts of the circles, joining *a b*, *f e*, *f a*, *e b*.

To draw a tangent to an ellipse.—(Fig. 196.)—Let *c* be the point of contact, and *a b* the foci; from *b* draw a line through *c*; make *c d*=*c b*; join *d a*, bisect it in *e*; from *e* draw through *c*—*e c* is the tangent. *Meth. 2nd.*—(Fig. 197.)—From *a*, *b*, the foci of the ellipse, to the point of contact at *c*, set off in *c a*, *c d*= *c b*; from *b* draw through *d*; draw from *c* a line parallel to *b d*—it is the tangent required.

An ellipse being given, to find its "foci" and diameters.—(Fig. 198.)—Draw any two parallel lines as from *a b*, *c d*; bisect them in *e e*: draw *e e*, bisect it in *f*—*f* is the centre of

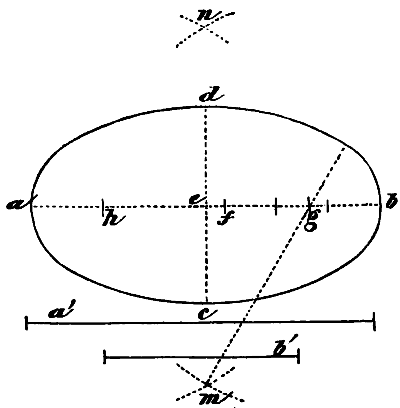


fig. 192.

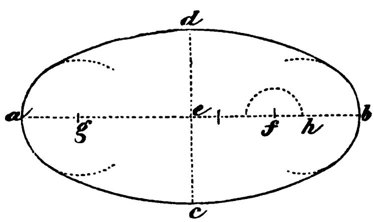


fig. 193.

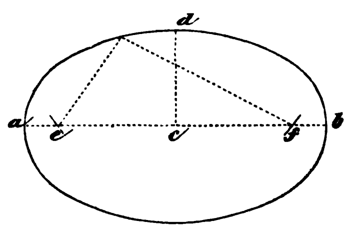


fig. 194.

the ellipse; from this, with any radius greater than half the supposed conjugate diameter, draw the circle *p b c*,

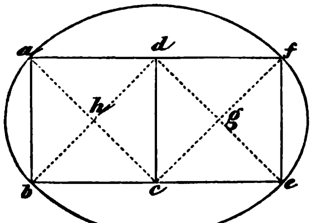


fig. 195.

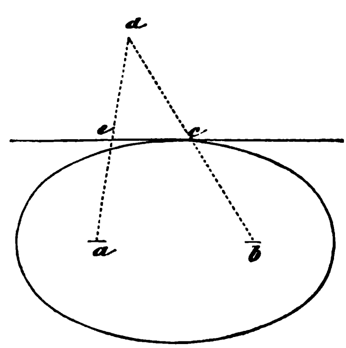


fig. 196.

cutting the ellipse in *h m*; join *h m*, bisect it; through the point of bisection and *f* draw a line *o o*; this is the transverse diameter; through *f* perpendicular to *o o* draw a line, meeting the ellipse—this is the conjugate diameter; bisect *f o* in *s*; make *f s*=*f s*—on both sides the conjugate, *s s*, are the foci.

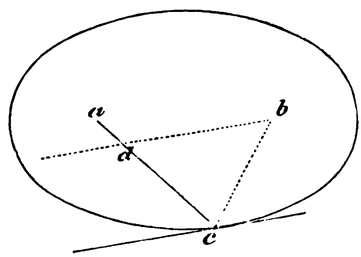


fig. 197.

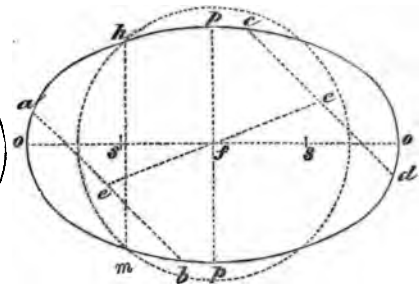


fig. 198.

To describe an ellipse on the large scale by means of points.—(Fig. 199.)—Let *a b*, *c d* be the two diameters; with *a e*, from *c*, lay on *c d* to *g*; from any point *m* between *e g*, with *e g*, cut *e b* in *n*; from *m* through *n*, draw a line and make this from *n*=*e d*; the point thus found is in the curve of the ellipse—any number to complete the curve may thus be found. *Meth. 2nd.*—Let *a b*, fig. 200, be half the trans-

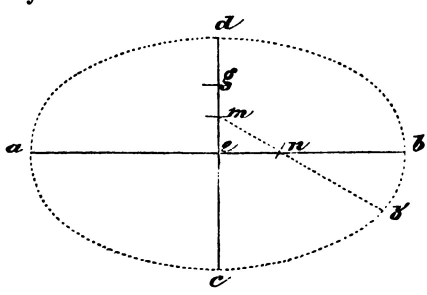


fig. 199.

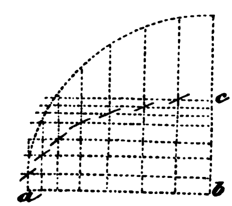


fig. 200.

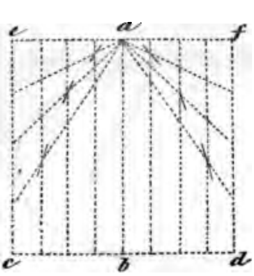


fig. 201.

verse, and *b c* half the conjugate diameter; draw *b c* at right angles to *a b*, and produce it indefinitely; from *b*, with *a b*, describe the quadrant. Divide *a b*, *b c*, into the same number of

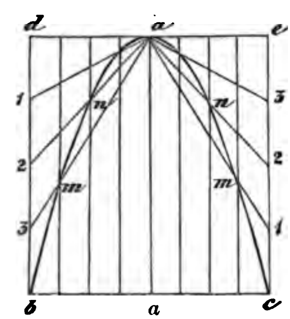


fig. 202.

equal parts; and from these draw lines parallel to *a b, b c;* through the points where the corresponding lines intersect as the first from *b,* with the first from *c,* draw a curve by hand—this is one quarter of the ellipse, the others may be produced in like manner.

THE BASE *c d* OF A PARABOLA. AND ITS ABSCISSA *a b,* BEING GIVEN TO FIND THE CURVE.—(Fig. 201.)—From *c* and *d* draw lines to *e f*—through *a,* parallel to *b d,* draw *e a f.* Divide *c b, b d,* each into any number of equal parts as four, also *c e d f.* From the points in *c d* draw lines to *e f,* parallel to *c e;* and from those in *c e, d f* to the vertex *a*—through the points where the corresponding lines intersect, as the first from c, with the third from *e,* draw by the hand the curve required—the various points may be correspondingly numbered to facilitate the operation. Fig. 202 gives another diagram, showing this construction—*a b, b c,* divided each into four parts, as also *c e, b,*—the points *n, m, n, m* are those through which the curve is drawn. In fig. 203 another method is shown—Draw the line *a b, c d;* divide *a b* into five=parts; through these draw lines to *d e, c f;* from the points on *d e* draw lines to *a,* and from *c,* through the points on *a b,* meeting those—through the points thus obtained draw the curve by hand.

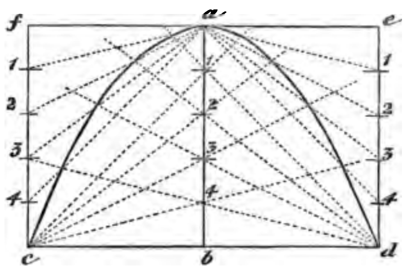


fig. 203.

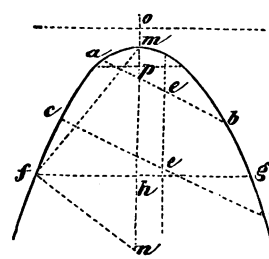


fig. 204.

A PARABOLIC CURVE BEING GIVEN, TO FIND ITS FOCUS, DIRECTRIX, AND PARAMETER.—(Fig. 204.)—Draw any two parallel lines, *a b, c d;* bisect them in *e e;* draw a line *e e* through these, this forms a diameter—at right angles to this draw any line *f h g,* bisect it in *h;* draw *h m o*—join *m f;* from *f,* at right angles to *m f,* draw a perpendicular cutting *m n* in *n*—divide *h n* into four equal parts—lay one of these from *m* to *p* and *o, p* is the focus—through this draw a line parallel to *f g*—it is the parameter—a line through *o* parallel to this is the directrix.

TO DRAW A TANGENT TO A GIVEN POINT IN THE CURVE OF A PARABOLA.—Let *a,* fig. 205, be the vertex, the point of contact, and *c* the point where the tangent will intersect the Parabola's axis produced. From *d* draw the semi-ordinate, *d e,* at right angles to *b e,* draw *a c=a e—d e* is the tangent.

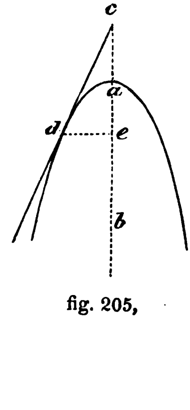


fig. 205,

To DRAW THE CURVE OF A HYPERBOLA, THE CENTRE *d*, FIG. 206, THE VERTEX AND ORDINATE *d c* BEING GIVEN.—Draw *a b* through the vertex draw *e, f*—and from *a b* parallel to *d e, a e, b f*—divide *a c, c b* into any number of equal parts as four, and draw from these to the centre *d* —divide *a e, f b* into the same number of equal parts, as *a b*, namely four, and draw from these to *e*—through the points where the corresponding lines intersect; draw the curve by hand.

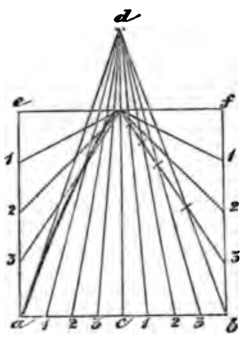


fig. 206.

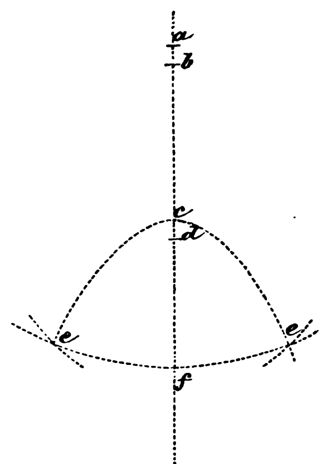


fig. 207.

To DESCRIBE A HYPERBOLA BY MEANS OF POINTS.—Draw any indefinite line *a f*, fig. 207; set off on it the transverse *b c*. Let *d* be the focus—equal to *d c*, from *b* set off to *a*; from *a*, with any radius greater than *b a*, describe an arc; from the radius take the transverse *b c*; and with this difference as a second radius, from the centre *d*, describe another arc, cutting the former one in *e e*. By this means any number of points may be found; the nearer they are the better.

To DESCRIBE THE CURVE "CYCLOID."—Let *a b c d*, fig. 208, be any circle; at right angles to *a b*, draw any line *b e*; make this equal to half of the circumference of the circle *a b c d*; this will be quickest done

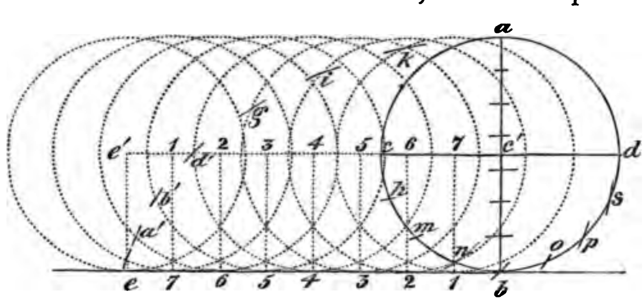


fig. 208.

by dividing *a b* into seven equal parts, and making *b e* equal to eleven of these; the proportion the circumference of a circle bears to the diameter being as 22 to 7. Divide *b e* into any number of equal parts, as eight, and number them as in the diagram; make *e e*ˋ at right angles to *b e*, and equal to *b c*ˋ; draw *c*ˋ *e*ˋ, and divide it into the same number of parts as *b e*; from each of these parts as centres, with radius *b c* describe circles; from the centres draw lines to the various points on *e b*. Divide *d b c* half of the circle, into as many parts as *b c* is divided into; then with radius *c h*, from the point 7 on *b e* cut the circle described from the point *e*; then with *c m*, from the point 6, cut the circle described from the point 1 on *c e*, in the point *a*ˋ; in the same manner with the distances *c n*, *c b*, *c o*, *c p*, *c s*; from the various points in *a b*, cut the circles in the points, *b*ˋ, *d*ˋ, *g*, *e*, *i*, and *h*—through the points thus found draw the curve.

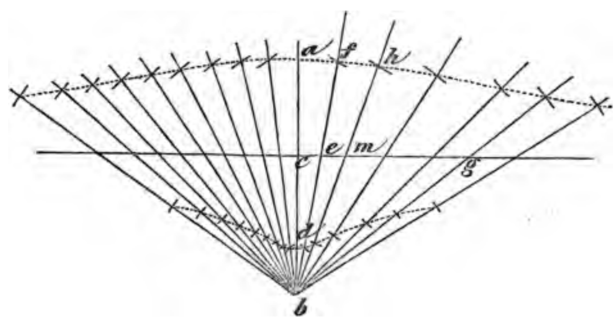


fig. 209.

To describe the curve "the conchoid."—Draw any two lines, as *a b*, *g e*, fig. 209, at right angles to each other; from *b* draw any number of straight lines as *d*, *e f*, *b m h*, *b g*; make on the line *a b*, *c d*= *c a*; and on each of the lines drawn from *b*, take *e d*=*e f*, *m h*=*a c*, and so on; through the points thus obtained, draw the curves—the upper curve *f*, *h*, is called the "superior conchoid"—the lower one the "inferior conchoid."

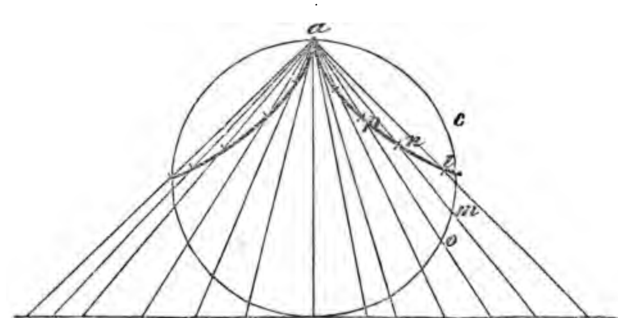


fig. 210.

To DESCRIBE THE CISSOID.—Let *a b c*, fig. 210, be a circle, and *d e*, any indefinite line touching it at *b*; from *a* draw any lines to points on the line *d e*, as to 1, 2, 3, 4, 5, 6, 7, and so on; with the distance *a m*, cut the line 8 *a* from 8 in *n*, and from 4, with *a o*, cut *a* 4 in *p*, and so on. Through the points thus found, on each side of *a b*, draw a curve as in the diagram.

To DRAW A SPIRAL ON A GIVEN LINE.—(Fig. 211.)—Let *a b* be the distance between each convolution—divide *a b* in *c*; from *c*, with *c b*, describe the semicircle *b a*—from *b*, with *a b*, the semicircle *a d*; from *c*, with *c d*, the semicircle *d e*—from *b*, with *b e*, to *f*—from *c*, *c f g*; from *b*, with *b g*, to *b*; from *c*, with *c b*, to *m*—the spiral is complete.

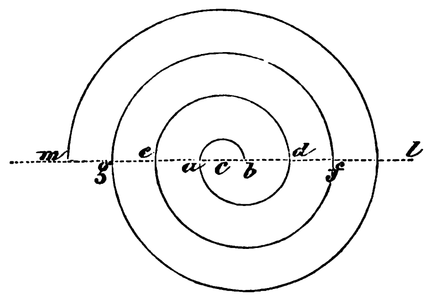


fig. 211.

Having thus fully explained the various methods of performing useful Geometrical Constructions, we shall show the application of Geometry to ARCHITECTURAL DRAWING.

GEOMETRY

APPLIED TO

ARCHITECTURAL DRAWING.

We shall first notice, under this division of our Work, the methods of describing the various "Mouldings," met with in Architectural Productions. We shall take them as near as possible in the order of their general sequence. The first we notice is the "Fillet," shown in fig. 212; this is so simple, that it requires no particular instructions as to the method of describing it.

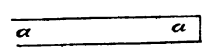


fig. 212

Fig. 213 is the "astragal."—Let b=the breadth, draw a line $b\ d$; make c the centre, take half of b, and as radius from c describe the semicircle; draw the horizontal lines $c\ e$.

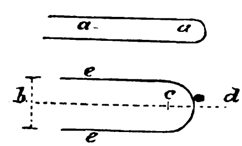


fig. 213.

Fig. 214 is the "torus."—The method of describing it—the breadth being given is the same as in last problem.

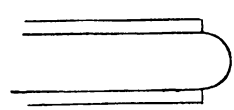


fig. 214.

Fig. 215 is the "scotia."—Let $a\ a$ be the top line, and $b\ b$ the bottom one; from a drop a perpendicular to b; divide this into three equal parts—from the first of these, from a, draw any line $e\ d$ parallel to a or b; from the point of intersection c, with radius $c\ a$, describe the semicircle $c\ d$; from d, with $d\ e$, describe part of a circle, meeting the line $b\ b$; draw the fillets $b\ b$, $a\ a$.

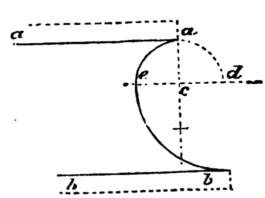


fig. 215.

Method 2nd.—Let $a\ a$, fig. 216, be the upper line, and $c\ c$ the lower; from a drop a perpendicular to c; divide $a\ c$ into 7 equal parts; through the third of these, from a. draw a line parallel to $a\ a$; from b, with $b\ a$, draw the semicircle $b\ d$; from d draw to e perpendicular to $b\ d$, produce $a\ a$ to e; from e draw through b, a line meeting the semicircle $b\ d$ produced in m—from e, as a centre, with $e\ m$ as radius, describe part of a circle to n.

Fig. 217 is the "echinus," "quarter round," or "ovolo."—Let $a\ b$ be the two points, join them by a line $a\ b$; divide this into 7 equal parts—

from *b*, with *b* 6, and from *a* with same radius, describe arcs, cutting in *c*; from *c*, with *c a*, describe the arc *a b*.

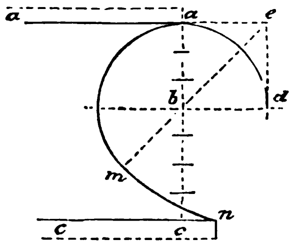


fig. 216.

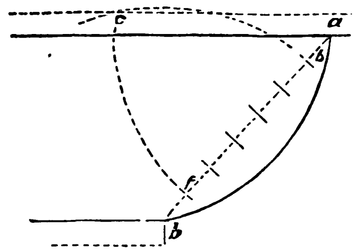


fig. 217.

Method 2nd.—Let *a b*, *c d*, fig. 218, be the two lines; draw *b d* perpendicular to *e d*; divide it into three equal parts; produce *c d* to *e*, and make *d e* equal two of the parts on *b d*; from *e* draw to *f*; join *d f*; from *d f*, with any radius greater than half, describe arcs cutting in *g*; from *g*, with *g f*, describe the arc *f d*,

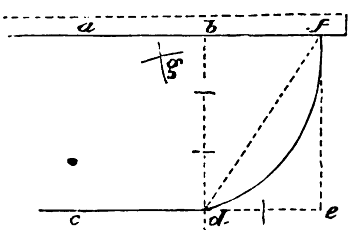


fig. 218.

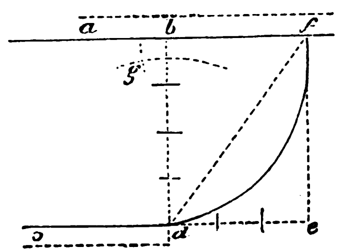


fig. 219.

Method 3rd.—Let *a b*, *c d*, fig. 219, be the lines; divide *b d* into four equal parts, make *d e* equal three of these; draw *e f*, and proceed as in last problem.

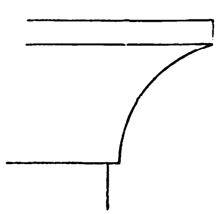


fig. 220.

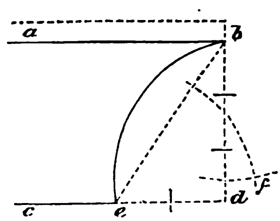


fig. 221.

FIG. 220 IS THE "CAVETTO," OR "HOLLOW." TO DESCRIBE IT.—Let *a b*, *c d*, fig. 221, be the lines at top and bottom; from *b* draw to *d* perpendicular to *a b*; divide *b d* into three equal parts—from *d* lay on *d c* to *e* equal to two of these; join *b e*; from *e* and *b*, with radius greater than half *e b*, draw arcs cutting in *f*; from *f*, with *f b*, draw the arc *b e*.

Method 2nd.—Let *a b*, *c d*, fig. 222, be the two lines; divide the perpendicular into five equal parts; make *d e* equal to four of these, and proceed as in last problem.

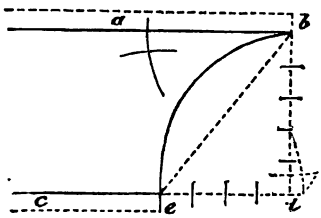


fig. 222.

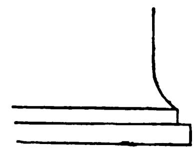


fig. 223.

FIG. 223 IS THE "APOPHYGEE" GENERALLY USED TO CONNECT A SHAFT OF A COLUMN, WITH ITS BASE. TO DESCRIBE IT.—Let *a b*, fig. 224, be the line of base, and *c* that of the shaft; produce *c* to *d*; divide *a d* into four equal parts; lay five of these from *d* to *e*; join *e d*, bisect it by arcs cutting in *f*—from *f*, with *f a*, describe the arc *a e*.

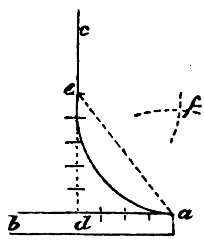


fig. 224.

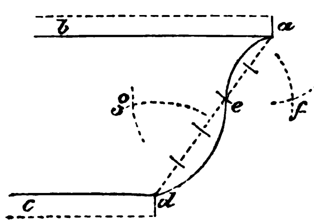


fig. 225.

FIG. 225 IS THE "CYMA-RECTA." TO DESCRIBE IT.—Let *a b*, *c d*, be the lines, join *a d*, divide it into five equal parts; bisect the part *a e* (the point *e* is the third from *d*) by arcs cutting in *f*; and the part *d e*, by arcs in *g*. From *f*, with *f a*, describe the arc *a e*; and from *g*, with *g d*, an arc *e d*—the moulding is complete.

Method 2nd.—Let *a b*, *c d*, fig. 226, be the lines, drop a perpendicular to *e*; produce *c d* to *e*; make *d e*=*e b*; join *d b*, divide it into

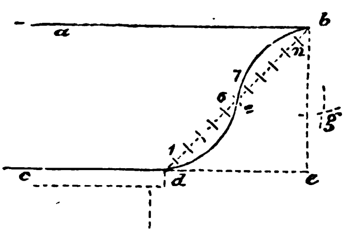


fig. 226.

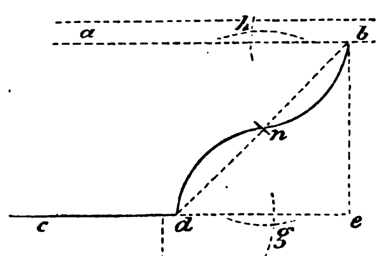


fig. 227.

twelve parts; from *d* and *e* (the sixth of these), with radii *d* 5, *e* 1, describe arcs cutting in *f*; from *e* and *b*, with radii *e* 11, *b* 7, arcs cutting in *g*; from *f* and *g* as centres, with radii *f d*, *g b*, describe arcs meeting in the point *e*.

FIG. 227 IS THE "CYMA-REVERSA." TO CONSTRUCT IT.—Let *a b*, *c d*, be the lines; produce *c d* to *e*, and drop a perpendicular from *b*; from *e*, with *e b*, describe an arc cutting *c e* in *d*; join *d b*, bisect it in the point *n*; from *d* and *n*, with radius greater than half *d n*, describe arcs from the point of intersection as centre, describe an arc *d n*; from *n* and *b*, with same radius, describe arcs cutting in *h*; from *h*, with *h b*, describe an arc meeting the arc *d n* in *n*.

FIG. 228 IS THE "OGEE." TO CONSTRUCT IT.—Let *a b*, *c d*, be the lines; join *b d*, divide it into four=parts; through the third of these from *d*, as *e*, draw a line parallel to *a b*. With the distance *e b*, from *e*, lay on *e f* to *h*; from *h*, with same distance, describe a semicircle to *o*; draw *h o* parallel to *e b*, cutting the semicircle described from *h*, in the point *o*; join *o d*, bisect it by arcs meeting in *g*; from *g*, with *g d*, describe the arc *o d*.

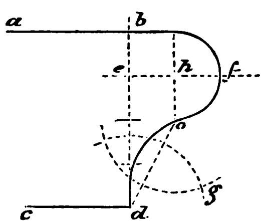


fig. 228.

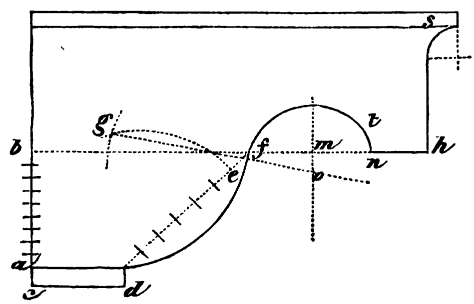


fig. 229.

We now proceed to give examples of various MOULDINGS, with the method of describing them.—Draw the line *a b*, divide it into nine equal parts; from *b* draw to *h*, at right angles to (fig. 229) *a b*; take any point *f* for the termination of the quarter round, from the end of the fillet *c d*; join *f d*, divide it into seven equal parts; from 1 and 6, with 1, 6, as radius, describe arcs cutting in *g*; from *g*, with same radius, describe the quarter round; from *f*, make *f n* equal to ten of the parts in *a b*; bisect *n f* in *m*; draw a line through *m* parallel to *a b*. From *g*, through the point where the arc 6 *g* intersects *f b*, draw the line *g f o*; make *h n* equal to four and a half parts of *a b*; from *o* as a centre, with *o f* as radius, describe an arc to *t*; from *m*, with radius *m n*, describe another meeting this. This moulding is met with in the Tuscan order.*

* See the Work in the present series on "Architectural, Engineering, and Mechanical Drawing."

To DESCRIBE THE MOULDING IN FIG. 230.—Draw any two lines cutting in *c*; with *c b* as radius, describe a semicircle, *c a d*; divide *c d* into two equal parts; make *d e* equal to one of these; drop a perpendiculr from *e* to *f*; make *f g* equal to *c d*, and *g h* to *d e*; from *e* and *h*, with radius greater than half the distance between them, describe arcs cutting in *m*—*m* is the centre of the arc *e h*.

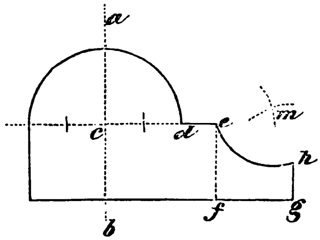


fig. 230.

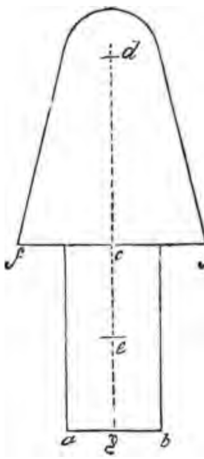


fig. 231.

To DESCRIBE THE MOULDING IN FIG. 231.—Draw any line *d g*; divide *g d* into two equal parts at *c*; divide *c g* also at *e*; make *c f*, *c f*, equal to *c e*; bisect *c f*, and make *g b*, *g a*, equal to it; from *a* and *b* draw to *f c f*, perpendicular to *a g b*; from *d* describe the semicircle with radius *g b*; join the points *f f* with the extremities of this.

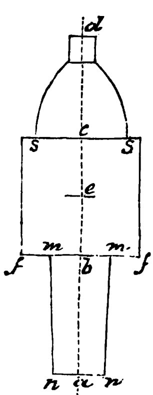


fig. 232.

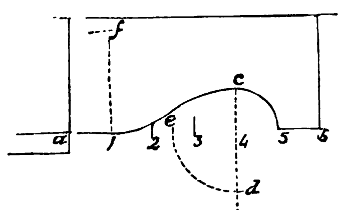


fig. 233.

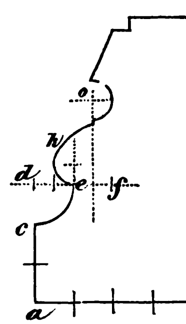


fig. 234.

To DESCRIBE THE MOULDING IN FIG. 232.—Draw the line *a d*; make *a b* equal to *b c*; bisect *c b* in *e*; draw through *c* and *b* lines *f f*, *s s*, at right angles to *d a*; make *b f*, *s c*, equal to *b e*; bisect *b f*, *b f*, in *m m*; join *m n*, *m*, *n*. The remainder of the moulding will be easily drawn from inspection of the diagram.

To DESCRIBE THE MOULDING IN FIG. 233.—Draw *a b*, and divide it into six equal parts; through the fourth of these draw a line *c d* at right angles to *a b*; bisect the distance between 2 and 3 in the point *e*; from

4, with 4 *e*, describe the arc *d e*; from the point 1, draw 1 *f* perpendicular to *a b*, and make it equal to *a e*; from *f* as centre, with *f* 1, describe an arc; from *d*, with *d e*, describe a second arc, and from the point 4, with 4, 5, the arc *c* 5; the three arcs joining will describe the curve as in the diagram.

To describe the moulding in fig. 234.—Draw *a b*, divide it into four equal parts; make *a c* equal to two of these, and *c d* equal to one; through *d* draw *d f* parallel to *a b*; from *d*, with *d c*, describe the arc *c e*; make *e f* equal to *e d*; from the centre, above *e*, describe the part of the circle to *h*; from *f*, with *f h*, describe the curve meeting the semicircle described from *o*.

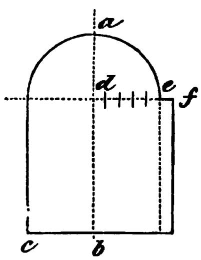


fig. 235.

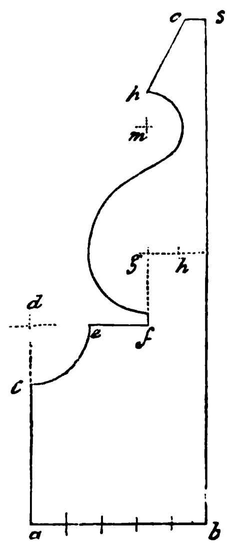


fig. 236.

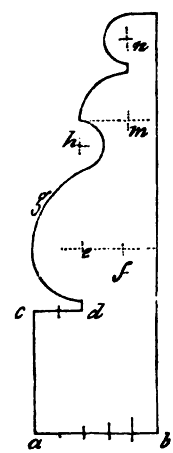


fig. 237.

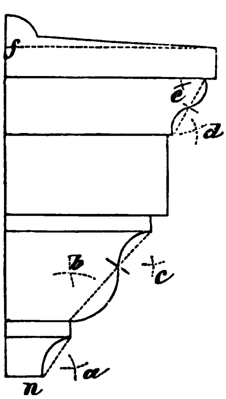


fig. 238.

To describe the moulding in fig. 235.—Draw *d e f*; and the semicircle *a e*, with radius *d e*; divide *d e* into five equal parts; make *e f* equal to one of these; make *d b* equal to twice *d e*; from *f* draw a perpendicular, meeting *c b* produced.

To draw the moulding in figure 236.—Draw *a b*, divide it into five equal parts; make *c d* equal to four of these; through *d* draw *d f* parallel with *a b*; from *d*, with *d c*, draw the arc *c e*; make *e f* equal to *d e*; divide *e f* into five parts; make the line above *f* equal to one of these; draw *f g* equal to six of these; from *g*, with radius *d e*, describe the arc; bisect *g f*, and lay the distance to *h*—it is the centre of the curve, meeting the semicircle described from *m*; join *n o*, *o s*.

To describe the moulding in fig. 237.—Divide *a b* into five equal parts; make *a c* equal to *b a*; make *c d* parallel to *a b*, and equal to two parts; from *e*, with *c d*, describe the arc; *f*, *h m*, *n*, are the centres from which the other arcs are described.

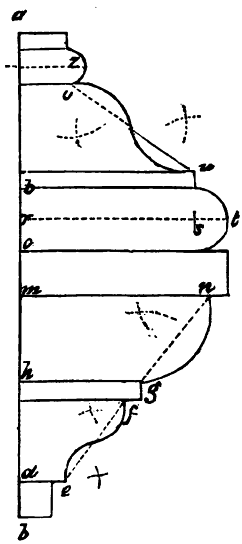
The mouldings in fig. 238 may be drawn easily by inspecting the figure; *a b*, *c d*, *e* and *f*, are the centres of the curves; the measurement for the height of fillet must be taken from the base *n*, on the line *n f*.

In drawing the mouldings in fig. 239 the base *b* must first be drawn, then the line *a b* at right angles to it; the respective depths of the mouldings must be laid down on this line, as *d*, *h*, *m o*, and *p*; *t*, *t*, 2. are the centre lines of the torus *s* and 2; *e f* is a "cyma reversa;" *g n* the quarter round; *w v* the "cyma recta."

We shall now proceed to give illustrations of the different varieties of Arches, with explanations as to describing the curves geometrically; the first we shall notice is the

Semicircular Saxon Arch.—(Fig. 240.)—Draw the line *c*, and perpendicular to it *a b*; from *c* lay off to *e e*, and with *c e* describe the semicirle.

To describe the Norman or Horse-shoe Arch.—(Fig. 241.)—Draw the line *e b*, and perpendicular to it another *b a*; from *b* lay off to



fig, 239.

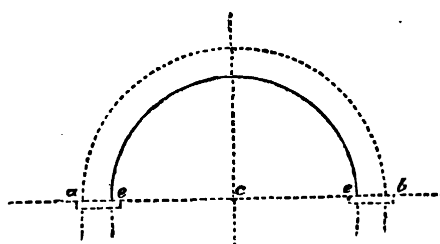


fig. 240.

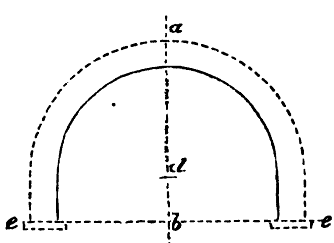


fig. 241.

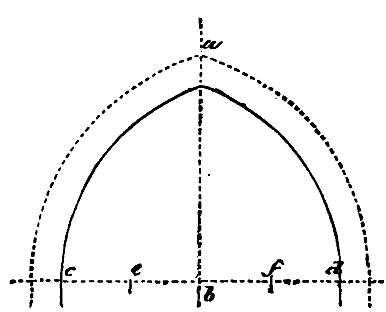


fig. 242.

d, and from *d*, with *b e*, describe the arch; draw perpendicular lines joining the extremities of the arch with the line *e b e*.

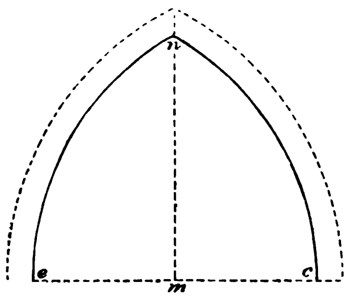


fig. 243.

TO DESCRIBE THE POINTED HORSE-SHOE ARCH.—(Fig. 242.)—Draw the line *c b*, *b a*, perpendicular to one another; divide *c b*, *b d*, each into two equal parts at *e*, *f*; from *e*, with *e d*, describe an arc, and from *f*, with *f c*, another, both meeting in *a*.

TO DESCRIBE THE EQUILATERAL ARCH, OR EARLY ENGLISH ARCH.—(Fig. 243.)—Draw *c e*, *m n*, at right angles to each other; make *m e* = *m c*; from *e*, *c*, with radius *e c*, describe arcs meeting in *h*.

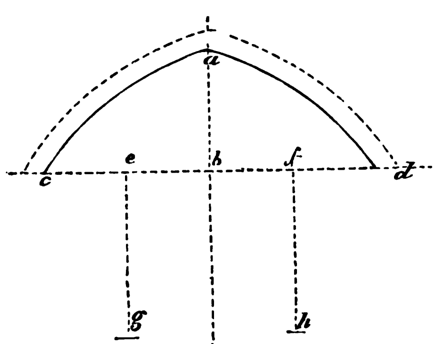


fig. 244.

TO DESCRIBE THE EARLY ENGLISH ARCH, GIVEN IN FIG. 244.—Draw the lines *a b*, *c d*, at right angles; divide *c b*, *b d*, into two equal parts at *e* and *f*; from these points draw lines to *g*, *h* perpendicular to *c d*, and make *e g*, *f h*, equal to *e f*; from *g* and *h* as centres, with radius *g d*, or *h c*, describe arcs meeting in *a*.

TO DESCRIBE THE LANCET ARCH, IN FIG. 245.—Draw *c h*, *f d*, at right angles. Let *a b* be the breadth, and divide it into three equal parts; lay four of these from *a b* to *h*; from *a b*, with *a b*, lay to *d* and *f*; from these, as centres, with radius *d b*, *f a*, describe arcs cutting in *h*; *o o* are centres, from which the dotted arcs are put in.

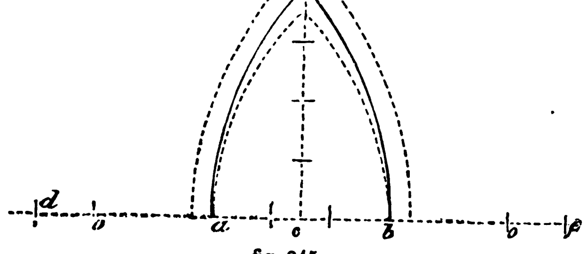


fig. 245.

TO DESCRIBE THE "SEMI-ELLIPTICAL ARCH," IN FIG. 246.—Let *a b* be the breadth, and *g f* its height; divide *a g*, *g b*, into two equal parts, at *d* and *c*; from *d*, *c*, with *d c* as radius, describe arcs cutting in *g*; from *c d*, with radius *c b*, describe parts of circles; from *g* draw through *c*, *d* to *m n*; from *g*, with radius *g n*, or *g m*, describe part of circle joining *m n*.

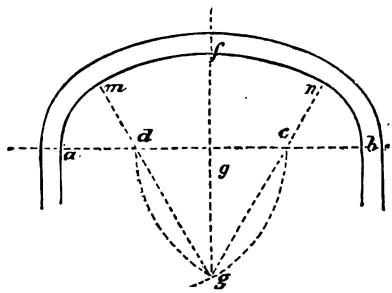


fig. 246.

TO DESCRIBE THE ELLIPTICAL ARCH, IN FIG. 247.—Draw the line *a b*, divide it in the point *e*, and draw a line perpendicular to *a b*, through this; divide *e a*, *e b*, into two equal parts at *c*, *d*; from *a b*, with radius *a d* or *b c*, describe arcs cutting the line *e* produced; from *d c*, with radius *d b*, describe parts of circles to *t t*; divide *a e*, *e b* into three equal parts, and lay one of these from *e* to *m n*; from *m n*, through *o*, draw lines to *g h*; from *a b*, with *a b*, cut these in *g h*; from the points *g h*, with radius *g t*, describe arcs joining *t t*.

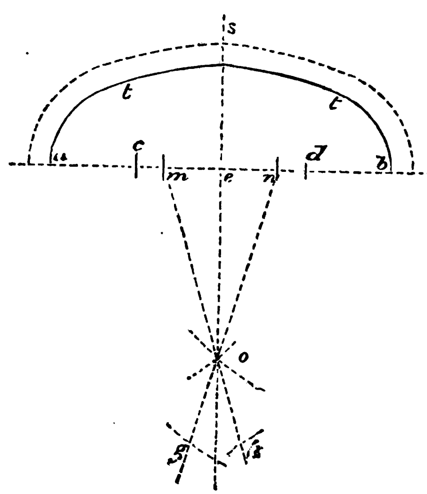


fig. 247.

TO DESCRIBE ANOTHER FORM OF ARCH IN THE SAME STYLE.—Draw *c d*, *a b*, fig. 248, at right angles; divide *c b*, *b d*, into two equal parts at *g* and *f*; divide *g c*, *f d* into equal parts at *h e*; from *g f*, with radius *g c*, describe arcs or parts of circles to *m n*; from *c d*, with radius *c h*, or *d e*, describe arcs below *c d*; then with *c d* as radius, from *g* and *f* cut these; from *o o*, with *o m*, *o n*, describe arcs meeting in *a*.

TO DESCRIBE ANOTHER FORM.—Draw *a b*, *e m*, fig. 249, at right angles; divide *a m*, *b m*, into four equal parts; from *c* and *d* (the first of these from *a*, *b*), with radius *a b*, describe parts of circles to *t* and *s*; from *c d*, with *c d*, describe arcs, cutting the perpendicular, drawn through *m* in *f*; from *d c*, through *f*, draw lines to *g* and *h*; with *a b*, from *c* and *d*, cut those lines in *g h*; from *g h*, with *g s*, or *g t*, describe arcs cutting in *e*.

We shall now proceed to describe the method of constructing Arches used as Canopies for Niches, &c.

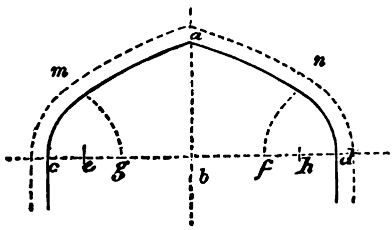


fig. 248.

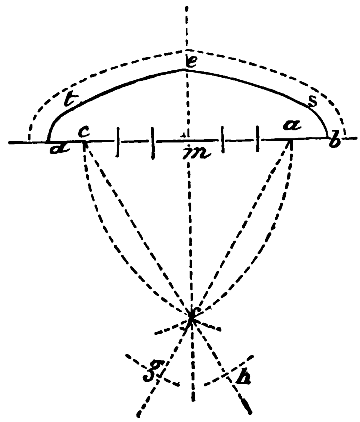


fig. 249.

To DRAW THE FORM IN FIG. 250.—Make *a b*, *c d*, at right angles; divide *a d*, *d b*, into five equal parts; lay one of these from *d* to *e e*; let *c d* be the height of the arch; through *c* draw *f c g* parallel to *a b*; from *e e*, with radius *e b*, describe parts of circles to *m*, *n*; join *a c*, *b c*, bisect *c n*, *c m* (from where the lines *a c*, *b c*, cut the circles described from *e e*) in *o*; draw lines through the points of intersection of the bisecting circle, meeting *c g f* in *f* and *g*; from *f* and *g*, with radius *g n*, describe parts of circles joining *c m*, *c n*.

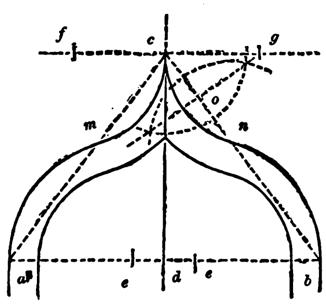


fig. 250.

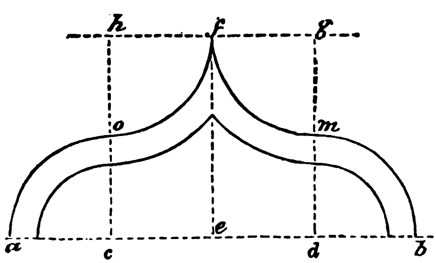


fig. 251.

To DESCRIBE THE FORM IN FIG. 251.—Let *a b* be the breadth, and *e f* the height of the canopy arch, equal to half *a b*; draw lines *a b*, *e f* at right angles; divide *a e*, *e b* into two equal parts at *c d*; from these points draw lines parallel to *e f*, meeting a line drawn through *f* parallel to *a b*; from *c d*, with *d b*, describe quadrants to *m o*; from *g h*, with same radius, describe other quadrants joining *o f*, *m f*.

To DESCRIBE THE FORM IN FIG. 252.—Let *c d* be the width, and *a b* the height; draw *a b* perpendicular to *c d*, and join *c b*, *d b* (only one-half of the diagram has the

constructive lines). Divide *a d, a c,* into two equal parts in *g* and *h*; from *g h,* with radius *g d,* describe arcs cutting *c b* in *o*; bisect *o b* in *m*; draw *h b s* parallel to *c d,* and through the intersection of the bisecting circles between *o b*; draw a line cutting *h b* in *h*; *h* is the centre of the circle, joining *o b*; divide *g d, c h,* into three equal parts; from *d, c,* lay off to *f f*; with *f d* lay from *a* in *a b* to *t*; from *h g* and *t.* with radius *d f,* describe the circles as in the diagram.

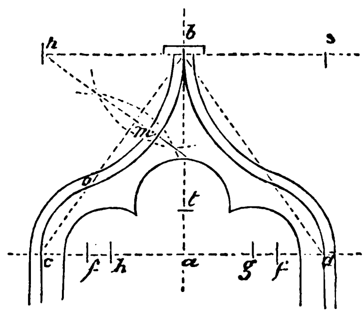


fig. 252.

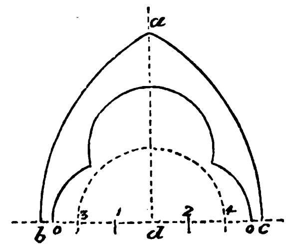


fig. 253.

To describe the example in fig. 253.—Let *c b* be the breadth; from *c b,* with *c b* as radius, describe arcs cutting in *a*; join *c a, b a,* and draw *a d* at right angles to *c d*; divide *b c, b d,* into three equal parts; from *d,* with *d* 3, describe a semicircle, cutting *a b* in *m,* the point 3. Bisect *a c, c b,* in the points *e e*; through the points of intersection of the bisecting circles, draw lines cutting the line *c d* in the points *o o*; from the divisions 1, 1, on the line *c d,* and the division 3 on the line *a b,* with radius 1, *o,* describe arcs meeting in *g* and *h.*

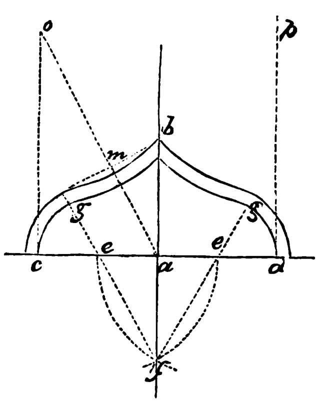


fig. 254.

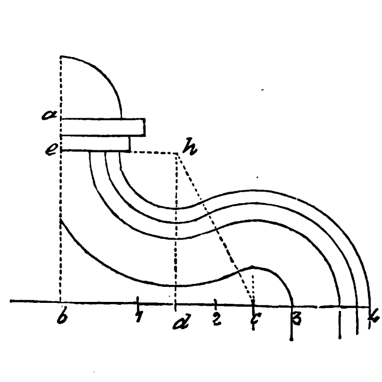


fig. 255.

To describe the Arch in fig. 254.—Draw the lines *a b, c d,* at right angles; divide *a d, a c,* into two equal parts at *e e*; from *e e,* with radius

e e, describe arcs cutting *b a* produced in *f*; from *f,* through *e e,* draw lines to *g g*; from *e e,* with *e e,* describe arcs to *g g*; join *g b*; bisect it in the point *m*; from *a,* through *m,* draw a line, meeting a line perpendicular from *c* in *o*; from *o,* with radius *o g,* describe the arc *g b*; *p* is the corresponding centre to *o.*

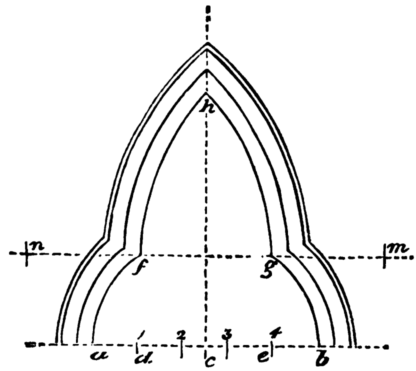


fig. 256.

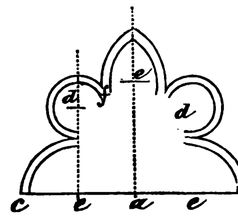


fig. 257.

To describe the Arch in fig. 255.—Draw *a b, b c* 4, at right angles; divide *b* 4 into four equal parts; bisect 1, 2, in *d,* and 2, 3, in *c*; from *c,* with *c* 3, describe the arc as in the diagram; make *b e* equal to two of the parts in *b c*; draw *e h* parallel to *b d*; join *d h*; by a line perpendicular to *b c,* form *c h*—*h* is the centre of the arc meeting *a b,* and that described from *c* as a centre.

To describe the Arch in fig. 256.—Let *a b* be the breadth; draw *c h* at right angles to this; divide *a b* into five equal parts; in *c n* draw the line *n m* parallel to *a b,* and at a distance from *a,* equal to two of the parts in *a b*; make *n o, o m,* equal to four of these—the points 1 and 4, in *a b,* and *n m,* are the centres from which the various arcs are described.

The Arch in fig. 257 is described from the centres *e d* and *f.*

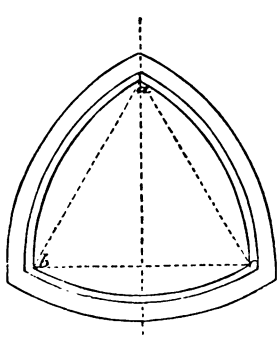


fig. 258.

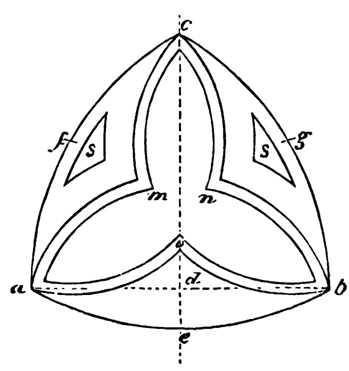


fig. 259.

TO DESCRIBE THE ARCHED WINDOW OPENING IN FIG. 258.—Describe an equilateral triangle *a b c*; *a b c* are the points from which the arcs are described.

IN FIG. 259 THE METHOD IS SHOWN OF DESCRIBING THE INTERNAL TRACERY-WORK.—Draw as before the equilateral triangle, and the outline curve; bisect *a c*, *b e*, *a b*, in the points *e*, *f*, *g*; from the point *e*, with radius *a e*, describe arcs to *m*, *n*, from *a* and *b*; from *f* and *g*, with same radius, other arcs, meeting in *o* and *m*, and *n*, from *a*, *b*, and *c*.

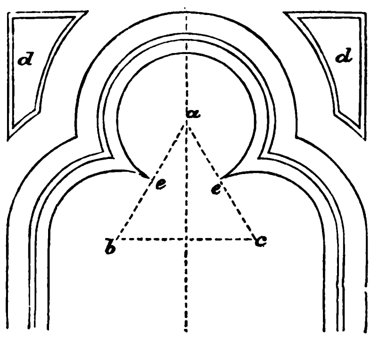


fig. 260.

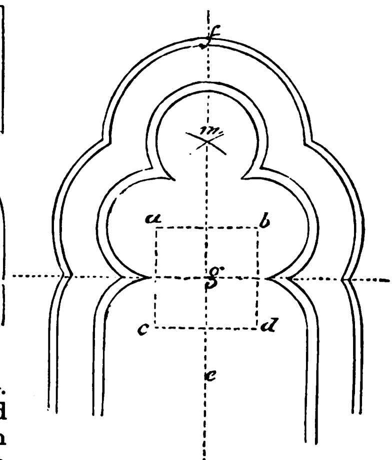


fig. 261.

TO DESCRIBE THE ARCH IN FIG. 260.—Draw a line *b c*, bisect it and draw perpendicular to it a line from *a*; make the point *a* distant from the line *b c* equal to half *b c*; bisect *a b*, *a c*, in *e e*; with *b e* as radius from *b c* and *a*, describe the arcs as in the diagram, and the curves of the sunk pannels *d d*.

TO DESCRIBE THE ARCH IN FIG. 261.—Draw *e f*, and at right angles to it the line *g*; on *g* make a square *a b c d*; from *a* and *b*, describe with radius *a b* arcs meeting in *m*; bisect any side of the square *a b c d*, and with the distance obtained as radius; from *a b*, *c*, *d*, and *m*, as centres, describe the arcs in the diagram.

TO DRAW THE INTERSECTING ARCHES IN FIG. 262.—Draw the line *e f*; let *c d* be the breadth of an arch; divide it in *b*, draw *b h*; make *d a*

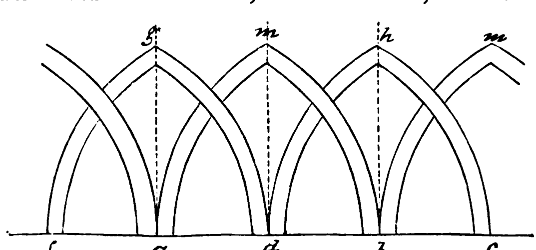


fig. 262.

equal to *d b*, and draw *a g*; *b h*, *a g* are the centre lines of two of the arches; *d m* is the centre line of the third.

TO DRAW THE INTERSECTING ARCHES IN 263.—*b b* are the centre lines of the two arches; *f f* those of the others; *c c*, *d d*, *o o*, are the centres of the respective arches; an inspection of the diagram will sufficiently illustrate the method of drawing them as given.

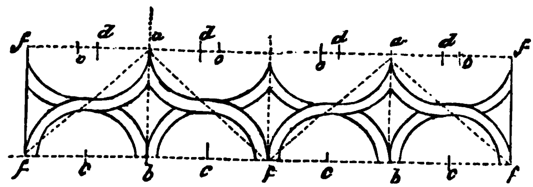


fig. 263.

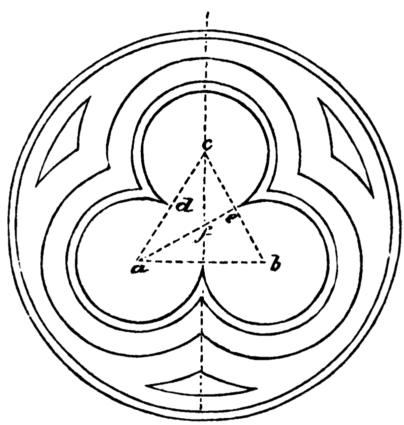


fig. 264.

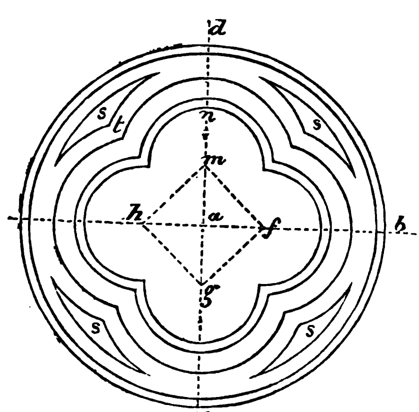


fig. 265.

TO DRAW THE TREFOIL AS IN FIG. 264.—The equilateral triangle *a b c* is first drawn, and the angle *b a c* bisected; a line drawn from *a* to *e*, cutting the line *c f*, gives the centre of the surrounding circles; *a b* and *c* are the centres of the trefoil curves.

THE QUATREFOIL, IN FIG. 265, is described from the corners, *h m*, *f g*, of a square; *a* is the centre of the surrounding circles, found by the intersection of the diagonals, *a b*, *c d*, of the square; the curves, *s s s s*, are drawn from the centre *a*; while those meeting in *t t t t*, are described from the centres, *h m*, *f* and *g*.

THE "CINQUEFOIL" ORNAMENT, IN FIG. 266, is described from the corners of a pentagon, *a b*, *d e f*, by dividing *e d* equally on the point *g*, and drawing a line from *a* to it, cutting the perpendicular *e* in *h*; the centre *h* of the surrounding circles is obtained.

THE ORNAMENT, IN FIG. 267, is described as follows:—Draw *a b*, *o d*, at right angles; divide *a c*, *c b*, into parts at *e*, *f*; parallel to *c d*, draw lines from

f and *e*; with *f c* or *c e*, lay from *f* and *e* to *g* and *h*; from these points as centres, with radius *g c*, describe parts of circles; divide *o d* into four equal parts; from *m*, the third of these, with radius *g c*, describe arcs meeting the lines produced from *f e* as in *n*, and the circles described from *g* and *h*; join *d n*; through *d*, parallel to *a b*, draw a line to *c*; bisect the line *d n*, and through the intersections of the bisecting arcs, draw a line to *c*—*c* is the centre of the arc joining *d n*.

In fig. 268 we give the Drawing of a Baluster.—*a* is the centre of the lower curves; the centres of the upper curves are found by drawing a line *c b*; from *a* and *b* describe arcs cutting in *d*; from *d*, with radius *d a*, describe an arc cutting the line *c d* in *c*—*c* is the centre of the curve.

Part of the Baluster (the central portion) shown

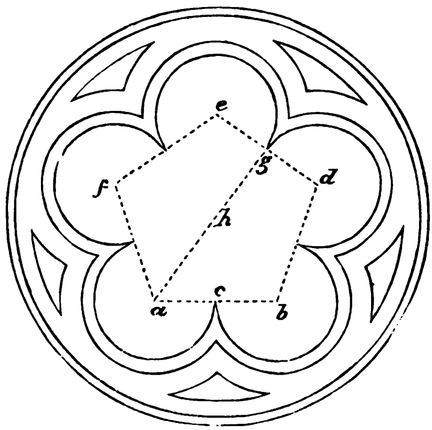


fig. 266.

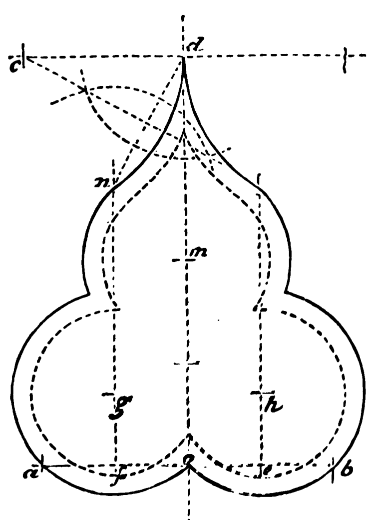


fig. 267.

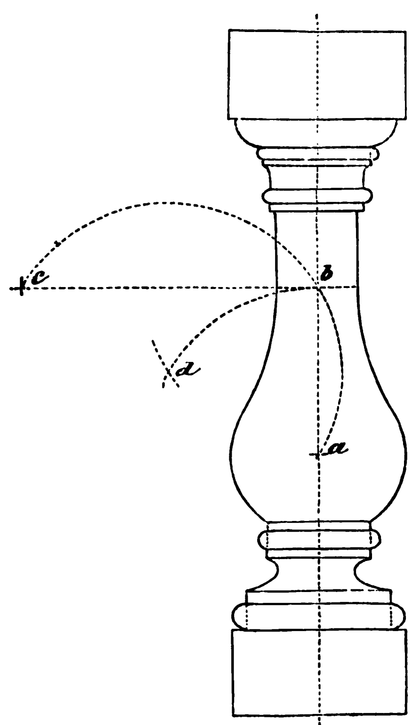


fig. 268.

in fig. 269, is drawn in a similar manner, as may be seen on inspection; the centre line is *a b*; the other centres are *c c*, *e* and *d*.

THE ORNAMENT IN FIG. 270 will be easily drawn by the assistance of the centres marked.

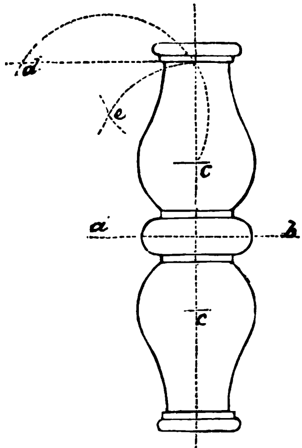


fig. 269.

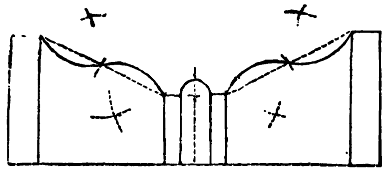


fig. 270.

We now proceed to give examples of VASES, with the mode of describing their contour or outline.

In the example, fig. 271, draw a centre line *b h*—the base *a b*, *c c*; the fillet *d*, and the occult line *f f*, *g g*; *f f*, *e e*, are the centres of the circles of the base; join *g h*; bisect it by the line *i i*, cutting *g g* in *k k*; from *k*, with radius *k h*, describe arcs *g h*; on the line *n n* the centres of part of the cap are found. In fig. 272 we give an enlarged view of the top portion of this Vase. Draw *a b*; through *e* draw *e e c*; make *d c* equal *d e*; *c c*, *d d*, are the centres for describing the base—*o* and *n* are the centres for the top.

In the form of Vase given in fig. 273, the centres for the base, *a a*, are on the line *c b c*; and at *h h*, on the line *f f*, *i i*, *m m*, and *n n*. In fig. 274 we give an enlarged view of the upper part of 273. The

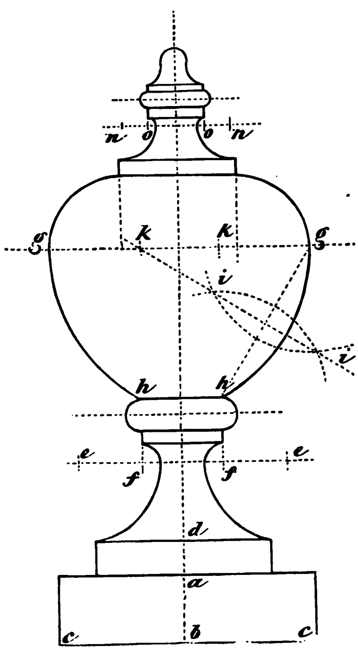


fig. 271.

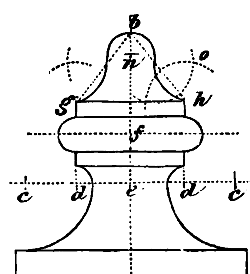


fig. 272.

centres *d e* are found by producing perpendiculars from *o o* to *d* and *e*, cut by lines drawn through the points of intersection of the bisecting circles of the lines *b o*, *c o*; the centre of the top circle at *h a* is found by bisecting lines *c a*, *b a*, and producing the lines of bisection, meeting the perpendicular from *a*.

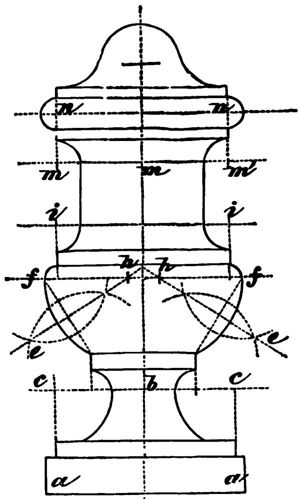


fig. 273.

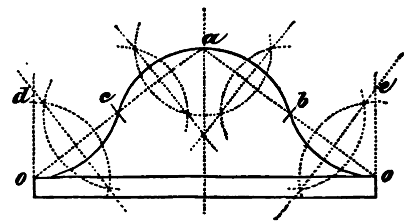


fig. 274.

The form of Vase in fig. 275 is described as follows :—Make the points *a a* distant from the ends equal to the height of the fillet forming the base; *a a* are the centres of the arcs; *b b*, and *c c*, are the centres of the top part of the base; *e e* are the centres for describing the arcs of the torus; make *b′ d*=to *a a′*; and lay off from *b′ h′* and *n′*; through h′ draw *h h′ h*; join *e h*, bisect it by a line *f d* produced, meeting *h h* in *g*; *g* is the centre of the arc *h e*; the arcs *h o*, *h o*, are described from the centres *s*; *m m*, *n n*, are the centres for describing the curve of the upper part.

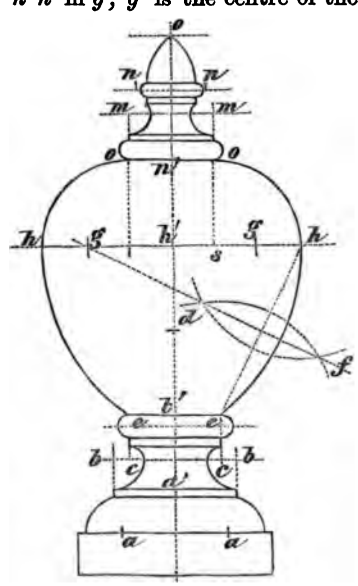


fig. 275.

The form of Vase in fig. 276 is described as follows:—Draw *a o*; form the base *a a*; make *b c* equal *a b*; and from *c* lay off three times *a b* to *b′*; bisect the last part in *f*; through *f* draw *g f g* parallel to *a a*; from *h h* describe the arcs to *e e*; join *d e*, *d e*, bisect them by lines produced, cutting *g f g* in *g g*; these are the centres of the arcs *d e*, *d e*; make *b′ n* equal to *b b′*, and draw *n m* and *i i*; *m′ m* are the centres from which the arcs *s s* and *o o* are described; *i i* the arcs *t t*, and *n′* the arcs *o v*.

In fig. 277 the upper part of a Vase is given—*n n*, *a a*, *b b*, *c c*, and

m, are the centres from which the curves are described. In fig. 278 the base of a Vase is given—*a b* is the centre line; *c c* the centres for the "torus" *c c c*, and *f f* for that at *f e f*; produce *f f* to *h h*, and *c c* to *d d*, meeting the line drawn through *g* parallel to *c c c*; *h h*, and *d d*, are the centres of the curves.

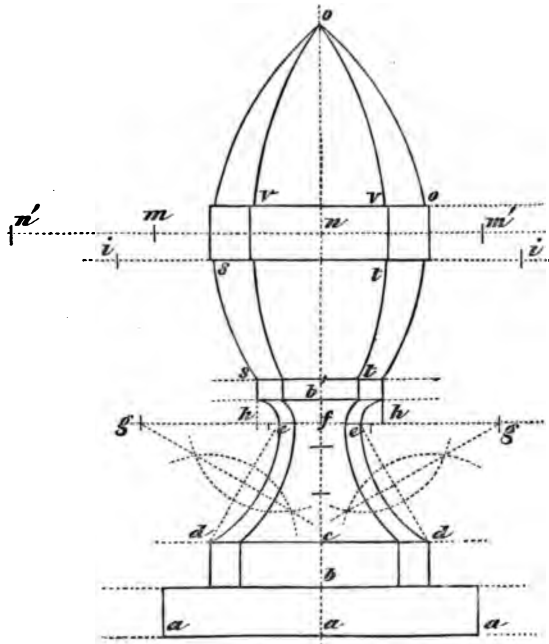


fig. 276.

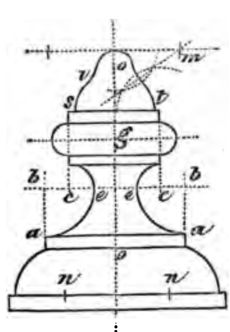


fig. 277.

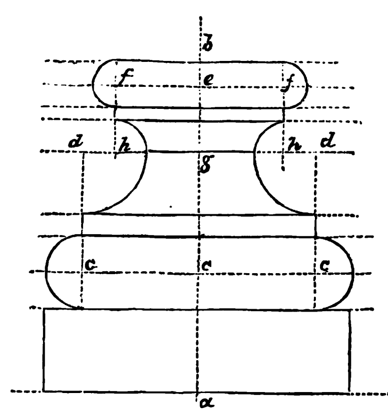


fig. 278.

To DESCRIBE THE PART OF THE HAND RAIL OF A STAIR SHOWN IN FIG. 279.—Draw *a b*, and at right angles to it, through the points *c d* and *e*; from *c* lay off to *g g*, and from these describe curves to *f f* and from *h h*; from *f f*, with *f f*, describe arcs meeting in *a*; with *a b*, from *a* describe the part of the circle joining the arcs from *g g*.

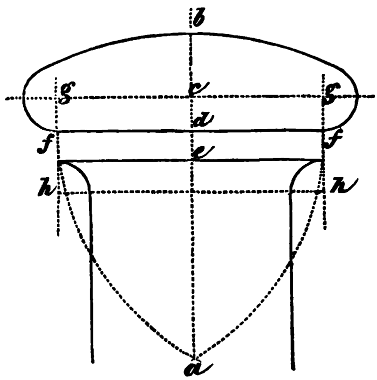


fig. 279.

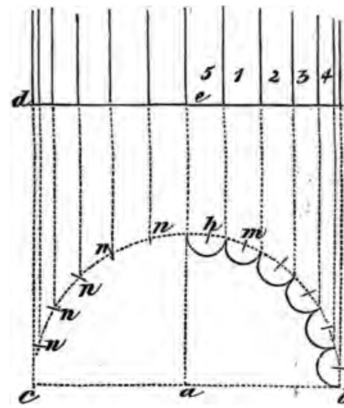


fig. 280.

THE MANNER OF DESCRIBING THE "FLUTES" OR HOLLOWS IN THE SHAFT OF A COLUMN IS SHOWN IN FIG. 280.—Let *b a c*, or *d e f* be the diameter of the shaft at its base; describe a semicircle *b h c*. Suppose there are to be 24 flutes in the shaft—divide *b h c* into 12 (half) equal parts; bisect each of these parts, and from the points as centres describe small semicircles, as in the diagram, or merely mark the points of division. as *h h*; parallel to *a b*, from the points, draw lines, as *c d*, *b f*; 1, 2 3, 4,5, shows the division between the flutes, lessening in breadth as they approach the outside line; thus giving the appearance of roundness or distance. When the shaft tapers towards the top, the diameter at the upper extremity is taken and divided as above described.

IN FIG. 281 THE METHOD OF DRAWING THE HOLLOWS IN CASES WHERE EACH IS DIVIDED FROM THE OTHER BY A NARROW BAND OR FILLET IS GIVEN. —*a b* is the semi-diameter of shaft; *c d* the line on which the semicircle is drawn; *n n n* is the breadth of the fillets.

To DESCRIBE THE SPIRAL SCROLL OF THE TERMINATION OF A HAND RAIL FOR A STAIR, AS IN FIG. 282.—On the line *a* draw a square, and divide it as in 283. From *a* describe the circle *n b e*; then from the point 1 (see fig. 283) describe the curve to *e*—from 2, from *e* to *d*; from the point 3, from *d* to *c*; from 4, from *c* to *f*; from 5, from *f* to *g*;

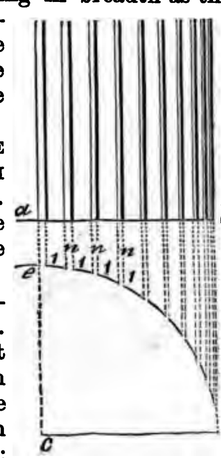


fig. 281.

from 6, *g h*. Suppose the breadth of rail to be *h p*; then from the point 6 draw the curve *p o*; from point 7, *o* to *n*.

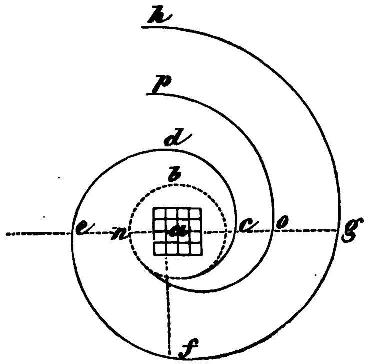


fig. 282.

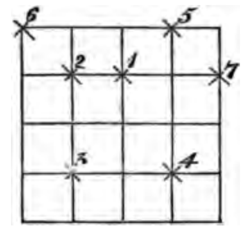


fig. 283.

FIG. 284 GIVES ANOTHER METHOD OF DRAWING A SCROLL TO THE TERMINATION OF A HAND RAIL.—From *b* draw a circle *a c*; divide its circumference into eight equal parts,

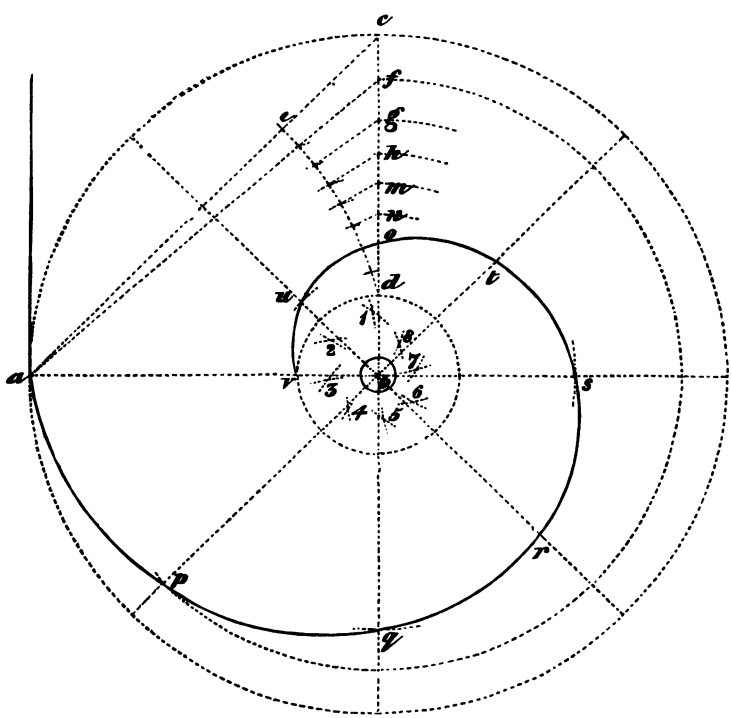


fig. 284.

and draw the radial lines; draw the circle *b d.* join *a c*; from *a* describe the arc *d e*, meeting *a c* in *e*; divide *d e* into eight equal parts; from *a* through these, draw lines meeting *b c* in the points *f g*, &c., &c.; from *b* as a centre, with *b f* as radius, describe a circle cutting the radial line *b p* in *p*; from *b*, with *b g*, the radial line *b q* in *q*; with *b h*, the line *b r* in *r*; *b m*, *b s*, in *s*; *b n*, *b t*, in *t*; *b o*, *b o*, in *o*, and so on. Then, with *b a* as radius, describe from *a* and *p* arcs meeting in the point 1; with *p b* as radius, from *p* and *q*, arcs meeting in the point 2; with *q b* as radius, from *q* and *r*, arcs cutting in the point 3, and so on, producing points 4, 5, 6, 7, 8. From the point 2, with radius 2 *a*, describe the arc *a p*; from 3, with 3 *p*, the arc *p q*; from 4, with 4 *q*, the arc *q r*, and so on.

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